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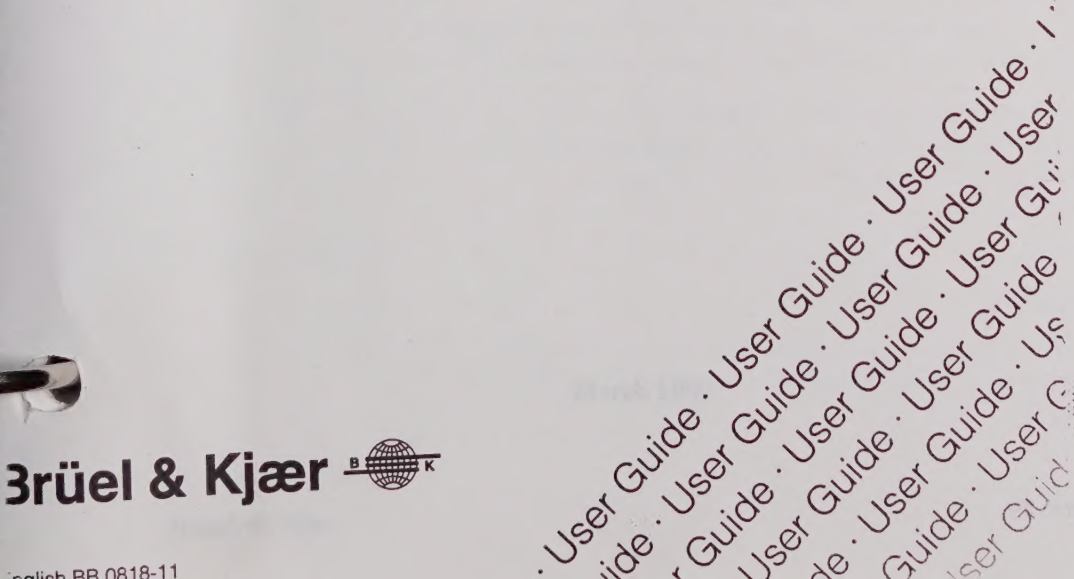
ual Channel FFT Option Type 7651

144 Frequency Analyzer

peration and Interface


User Guide · User Guide · User Guide ·

Dual Channel FFT Option
Type 7651

Valid for Type 7651 Dual Channel FFT Options
from serial no. 1 673 412 and Type 2144 Analyzers
from serial no. 1 614 490

March 1992

Brüel & Kjær

BB 0818–11

Safety Considerations

This apparatus has been designed and tested according to IEC Publication 348, *Safety Requirements for Electronic Measuring Apparatus*, and has been supplied in safe condition. The present User Guide contains information and warnings which should be followed by the user to ensure safe operation and to retain the apparatus in safe condition. Special note should be made of the following:

Powering the Apparatus

Before each use of the Power Supply ZG 0199 with the apparatus, check that it is set to match the available mains voltage and that the correct fuse is installed.

Safety Symbols

⚠ The apparatus will be marked with this symbol when it is important that the user refers to the associated warning statements given in the User Guide.

Warnings

- Switch off all equipment before connecting or disconnecting their digital interface. Failure to do so could damage the equipment.
- Whenever it is likely that the correct function or operating safety of the apparatus has been impaired, the apparatus must be made inoperative and be secured against unintended operation.
- Any adjustment, maintenance and repair of the open apparatus under voltage must be avoided as far as possible and, if unavoidable, must be carried out only by trained service personnel.

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Chapter 1

Introduction

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1.1 About Type 7651

Type 7651 is a dual channel FFT software option for Real-time Frequency Analyzer Type 2144. It comes on disk and is loaded using the analyzer's built-in disk-drive. A software key must be installed in the 2144 to allow the 7651 program to be executed. The FFT option turns your 2144 into a dual channel FFT analyzer with up to 2048 samples transform size (801 lines), real-time zoom, advanced cursor functions, and a frequency range to 25.6 kHz in both single and dual channel operation.

1.2 About This User Guide

This Guide is intended as a *supplement* to the 2144 User Guide Vols. 1 and 2. It assumes that you are familiar with the operating principles of Type 2144 and deals only with functions which are not available with the 2144. Most of these functions are dedicated FFT functions, such as time windows, zoom, and transform size.

Summary of Contents

Chapter 2 describes how to install the necessary software key and how to load the FFT option. It also gives an overview of the menus and describes a new method of parameter selection from the front panel.

Chapter 3 describes the measuring functions of the 7651 which differ from those of the 2144. For example, the cursor functions of the 7651 are extended.

Chapter 4 describes how to use the new menus and functions in greater detail.

Chapter 5 contains syntax diagrams and other information about the interface messages. This chapter is a supplement to the 2144 User Guide, Vol. 2 and does not repeat information which applies to both Type 2144 and Type 7651.

Specifications are given in Chapter 6 and the Index is in Chapter 7.

For information regarding the basic principles of operation (incl. interface), installation and maintenance, front and rear panel controls, etc., refer to the 2144 User Guide.

Chapter 2

Getting Started

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2.1 Installing the Software Key

To run the FFT option, a software key must be installed in the 2144. The key is a 24-pin integrated circuit which must be placed on circuit board 9 in the analyzer as described below (see Figs. 2.1, 2.2):

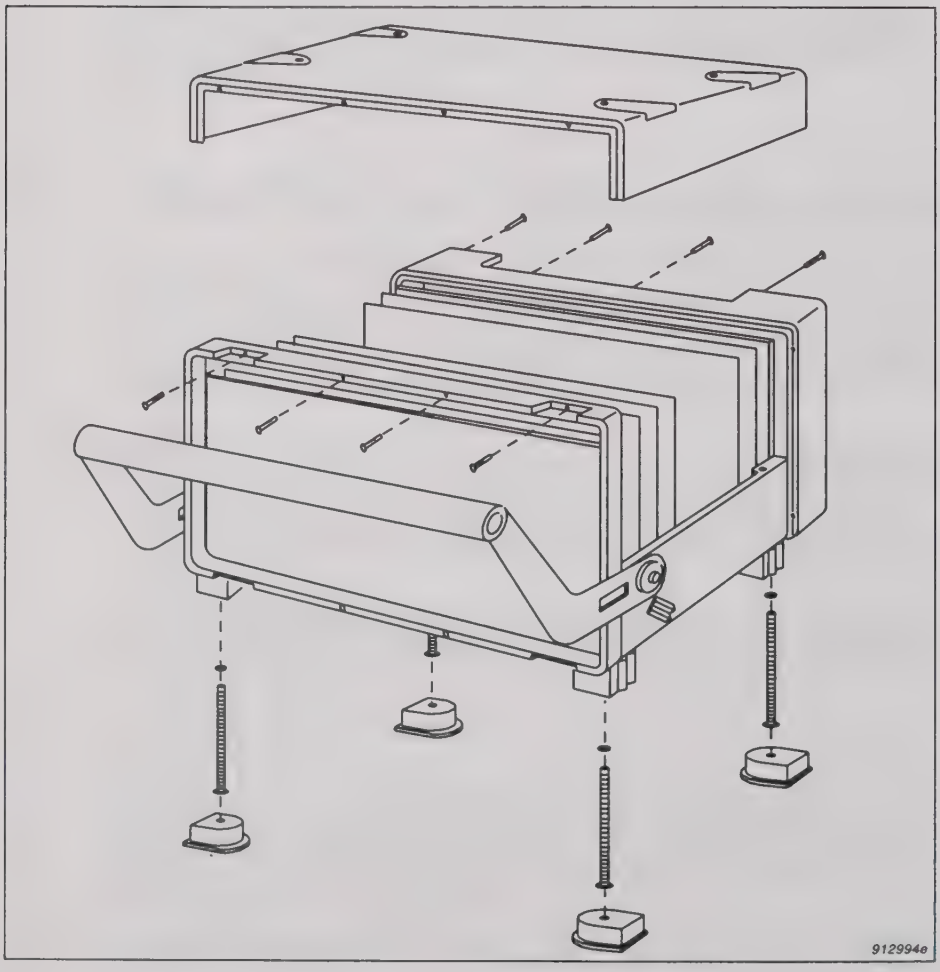

Fig. 2.1 Dismantling the analyzer

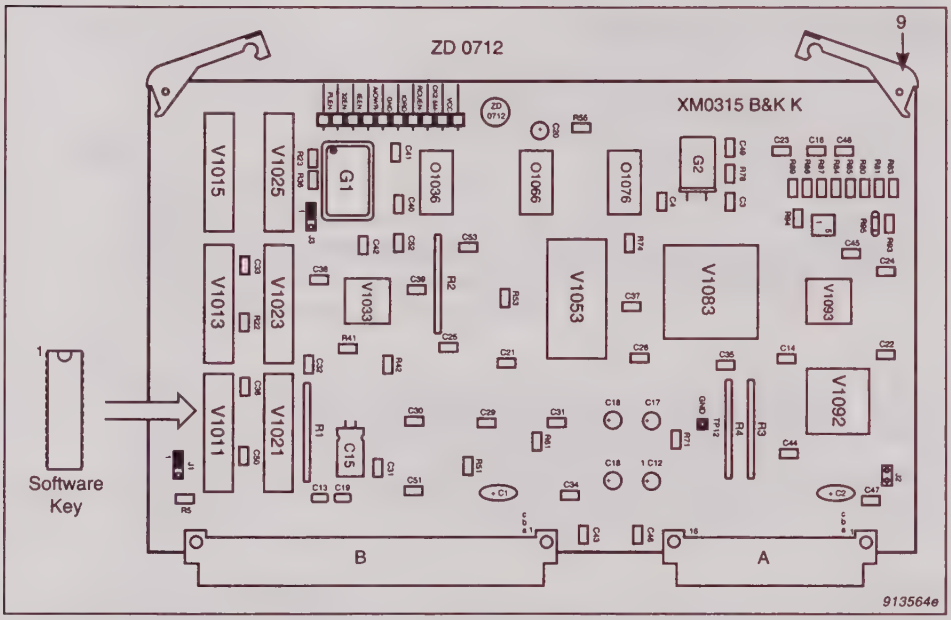

Fig. 2.2 Position of software key on circuit board 9

1. Make sure that the analyzer is switched off and disconnected from mains.
2. Remove the battery pack or power supply.
3. Remove the four rubber feet.
4. Unscrew the eight short screws at the top of the front and rear panels.
5. Unscrew the four long screws at the bottom.
6. Remove circuit board 9 (ZD 0712).
7. Place the software key (VP 5278) in one of the six sockets on the left-hand side of the circuit board as shown in Fig. 2.2. Any free socket may be used.
8. Reinsert the circuit board and reassemble the analyzer.

2.2 Loading the FFT Option

Before switching the analyzer on, ensure that you have read the "Installation and Maintenance" chapter of the 2144 User Guide Vol. 1. The same instructions apply to Type 7651.

Changing Type 2144 to 7651

The software for the FFT Option is contained on a 3½" floppy disk. To load the software into the 2144:

1. Switch on the 2144.
2. Go to the Memory menu and make a disk back-up of all the 2144 files in the analyzer's data memory that you want to keep.
3. Insert the disk containing the system software for Type 7651.
4. Make a Master Reset to load the 7651 software.

Changing Type 7651 to 2144

1. Switch on the 7651.
2. Go to the Memory menu and make a disk back-up of all the 7651 files in the analyzer's data memory that you want to keep.
3. Insert the disk with the system software for Type 2144.
4. Make a Master Reset to load the 2144 software.

2.3 The 7651 Menu Structure

An overview of how the menus are arranged in the 7651 is given inside the back cover of this guide. This can be used as a quick reference or whenever you want to locate a specific submenu.

The operating principle of Type 7651 is the same as for Type 2144 (with the addition of numerical selection of parameters – see section 2.4) and most of the menus are similar. However, the nature of an FFT analyzer, as opposed to a digital filter analyzer, necessitates some menu changes. The menus are briefly described below.

Measurement Type

This menu allows the selection of 1- or 2-channel analysis, or cross-analysis with phase-matched inputs.

Input

This is almost identical to the Input menu of Type 2144, the difference being that for cross-analysis, the 7651 allows the input channels to be set separately (A, B), or locked together (A&B) as recommended for intensity measurements. As an added feature, DC offset can be activated and de-activated.

Calibration

This is the same as for Type 2144 except for averaging time which is replaced by the number of linear averages. Calibration is always made using a fixed set-up independent of the measurement mode. The set-up is: 25.6 kHz frequency span, 800 lines, flat-top weighting and 0% overlap.

Time/Freq Parameters

This menu is used for setting the number of displayed lines (transform size) and the highest frequency for baseband analysis. Real-time zoom can also be selected together with centre frequency and frequency span (see sections 4.2 and 4.3).

Averaging/Channel Delay

This menu is for selecting linear and exponential averaging. It also controls overlap, overload reject, and a "start averaging" delay from channel A to channel B (see section 3.2).

Display Set-up

This menu is slightly different from the 2144 Display Modes menu as the display can be set up for both spectra and time records. This menu also controls frequency and time axis compression and bow-tie correction (see sections 3.5 and 4.6).

Time Weighting Function

Five time weighting functions (time windows) are available: Rectangular, Hanning, Flat Top, Transient and Exponential. Transient and Exponential windows have selectable position and width (see section 4.4).

Trigger/Multimode

This menu allows the selection of single measurements or the measurement of normal, gated or matrix multispectra. Trigger conditions can be selected for each of these options. See section 3.4. A peak hold function is included with the internal trigger.

Memory

The difference between this menu and that of the 2144 are that Spectrum Memory has been renamed Data Memory.

Measurement Text

This menu gives the same options as are available with the 2144.

Data View

This menu corresponds to Spectrum View of 2144. It differs from 2144, however, in the selection of data to view and in its extended cursor facilities. These options are as described for the Measurement Mode in section 3.6. In addition, OVL (overload slice) can be selected for the x-axis (see section 4.7).

Hold

Here maximum hold, minimum hold or both can be selected and applied to specific spectra, dependent on the measurement type. Hold can be activated for a particular frequency line or for all lines individually. Details are given on the corresponding help page.

I/O Interface

This menu is identical to that of the 2144.

Spectrum Calculator

These five menus correspond to the Spectrum Calculator and Spectrum Weighting menus in Type 2144. Further details are given in section 4.6.

Preselected Set-up

Similar to the corresponding menu of Type 2144. There is, however, only one default set-up available.

Autosequence
This menu is identical to that of the 2144.

Real-time Clock
This menu is identical to that of the 2144.

Back Lighting
This menu is identical to that of the 2144.

Measurement Mode
Use of the Measurement Mode and associated menus is described in Chapter 3.

2.4 Selection of Parameters

Where a single F-key allows the selection of one of several parameters, e.g. Functions (1–4): INST.A, AUTO.A, INST.B, AUTO.B in Measurement Mode Display Function for two-channel measurement, the desired setting can be selected either by toggling the F-key(s) or by numerical entry of the field number. In the above example, the fields are numbered 1 to 4, so that pressing **"3"**, followed by one of **"F4"** to **"F6"** will select the display of INST.B.

A similar method of numerical entry can be used for y-axis scrolling. The default value for the **Y-axis Scroll** keys is 5 dB. If, however, you want to use a larger or smaller step, for example 50 dB, simply press **"5" "0"** followed by one of the scroll keys and the display will be moved 50 dB in the required direction. Any further scrolling will also step 50 dB until a new value is entered or the analyzer is switched off.

Numerical selection of parameters via the IEEE bus is possible using **Key_Control**.

Chapter 3

Measuring with Type 7651

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3.1 Input

In order to take care of any DC offset in the analogue input module, a pure digital DC compensation can be selected by pressing **"F7"** in the Input menu. When this is set to **ON**, the analyzer performs a running DC evaluation and compensation. The digital DC estimate is reset when the attenuators or Input Type are changed

3.2 Averaging/Channel Delay

3.2.1 Averaging Mode

The Averaging Mode, linear or exponential, is set in the Averaging/Channel Delay menu using **"F1"**, or in Measurement Mode using the **Averaging Mode "Lin."** and **"Exp."** hard keys.

Number of Averages is set in the Averaging/Channel Delay menu using **"F2"** or in Measurement Mode (first page) using **"F2"**. Averaging "times" are given in number of averages rather than in seconds. The relation between these is given in equation (3.1):

$$T_{avg} = (N_{avg} - 1) \times \left(\frac{100 - OVLP}{100}\right) \times RL \; + \; RL \qquad (3.1)$$

where

T_{avg}	is the averaging time in seconds
N_{avg}	is the number of averages
$OVLP$	is the overlap percentage (see below)
RL	is the record length in seconds. This parameter is calculated by the analyzer and displayed (as Record Time) in the Time/Freq Parameters menu.

3.2.2 Overlap

The overlap percentage is set in the Averaging/Channel Delay menu using **"F4"**. Fixed overlaps of 0%, 50%, 67%, and 75% are available. MAX overlap maximizes the overlap according to the analyzer's set-up and increases the display update rate. It can be anywhere between 0 and 100%, depending on the settings of sampling fre-

quency, zoom, and trigger mode. The analyzer calculates an estimate for the overlap percentage and displays it on the left-hand side of the menu display.

The setting of Record Trigger (see section 3.3.1) in the Trigger/Multimode menu controls the `Free-run Overlap` field of the Averaging/Channel Delay menu. If this field is empty or inactive, it is because Record Trigger is not set to `FREE-RUN`.

3.2.3 Averaging Delay

Delay: Trigger → Ch. A
A delay can be set so that channel A starts averaging a specified period of time after a trigger is detected. This delay is set in the Trigger/Multimode menu using **"F2"** in Single Measurement mode (page 2) or Normal Multispectrum mode (page 3) and **"F1"** in Gated Multispectrum mode (page 4). This delay, which is described in the 2144 User Guide, can also be negative, resulting in information prior to triggering being included in the measurement.

Delay: Ch. A → Ch. B
In dual channel mode a delay can be set to start channel B averaging after channel A. This delay is set in the Averaging/Channel Delay menu using **"F3"**.

3.2.4 Overload Reject

If overload reject is switched on and an overload is detected, data will not be included in the averaging process for a period of time specified in the `Reject Hysteresis` field. You can enter your own values into this field (0 to 1000 s), based on your knowledge of the input signal and the overload messages displayed in the measurement mode. Here the overload is given as a percentage of the averaging time.

3.2.5 Autorange Time

The default autorange time is 2 s. In the Averaging/Channel Delay menu, it can be set to values ranging from 100 ms to 1 min.

3.3 Measurement Types

	Measurement Type:	1-ch*	2-ch	Cross
Time Domain Functions	A-channel time signal	•	•	•
	B-channel time signal	o	•	•
	Complex time	•	•	•
	A-channel autocorrelation	•	•	•
	B-channel autocorrelation	o	•	•
	Cross correlation			•
	Impulse response function h1			•
Frequency Domain Functions	A-channel instantaneous spectrum	•	•	•
	B-channel instantaneous spectrum	o	•	•
	A-channel autospectrum	•	•	•
	B-channel autospectrum	o	•	•
	Cross spectrum			•
	Mean sound pressure			•
	Particle velocity			•
	Complex intensity			•
	Frequency response function H1			•
	Frequency response function H2			•
	Frequency response function H3			•
	1 / frequency response function H1			•
	Coherence between channels A and B			•
	Coherence between mean pressure and particle velocity			•
	Coherent output power			•
	Non-coherent output power			•

* 1-channel mode uses either A- or B-channel as input

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Table 3.1 Available display functions for each of the three Measurement Types

The Measurement Type menu concept is the same as in the 2144, but the Measurement Types are different. Table 3.1 shows the avail-

able Display Functions for each Measurement Type. These are selected in Measurement Mode on the `Display Func.` page (see section 3.6.2).

Saving data in 2-channel mode takes up twice as much memory space as in 1-channel mode since two parameters are measured simultaneously and saved with each measurement.

Saving data as cross-spectra in cross mode takes up four times as much memory space as in 1-channel mode since four parameters are measured simultaneously and saved with each measurement. By saving the data as time records instead, half the memory can be saved for other use.

The collective name used in this User Guide for 2-channel mode and cross mode is **dual channel mode**.

3.4 Trigger/Multimode

The 7651 has four analysis modes: Single Measurement, Gated Multispectrum, Normal Multispectrum/Time Capture, and Matrix Multispectrum. These, together with the trigger conditions, are set up using the Trigger/Multimode menu.

3.4.1 Trigger Types

Type 7651 uses two types of trigger: Measurement Trigger which enables averaging (single/gated) or starts the collection of spectra in an opened file (normal/matrix), and Record Trigger which starts the collection of one block of data and average. The settings for these triggers are explained for each measurement mode in the following subsections. Note, however, that only one of the two triggers can be freely selected at any one time – the other depends on the measurement mode selected. The setting of Clock Trigger is explained in the 2144 User Guide.

It is important to note that Type 7651 does not have the "trigger active/inactive" function present in Type 2144; in the 7651, all measurements are triggered.

3.4.2 Single Measurement

Fig. 3.1 illustrates the collection of a Single Measurement. The figure applies to the collection of both spectra and time records and shows only one channel.

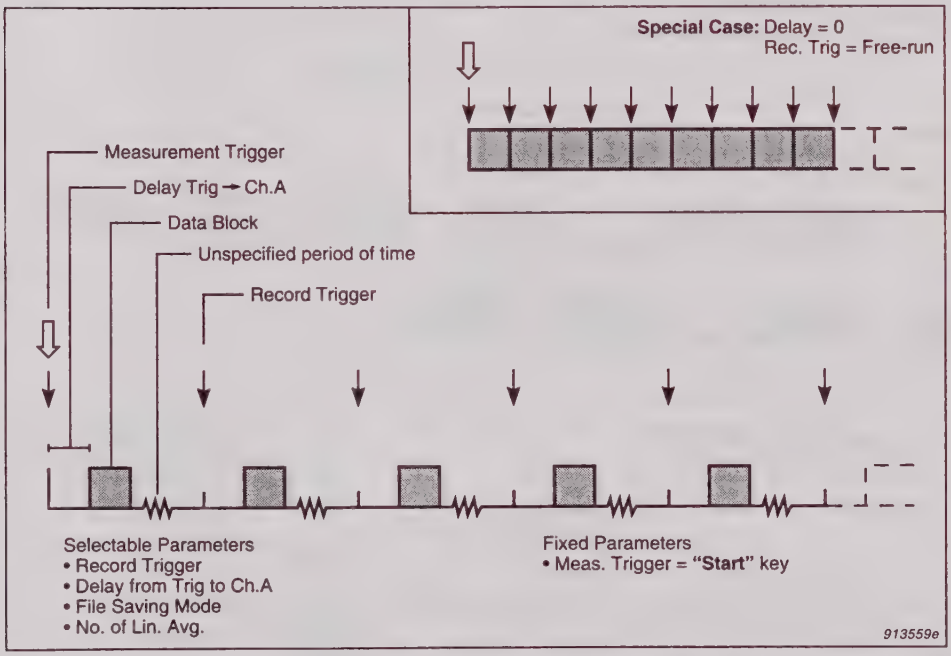

Fig. 3.1 Selectable parameters for data collection in Single Measurement mode

The Measurement Trigger is always FREE–RUN in Single Measurement mode. This means that the measurement starts when the **Averaging Control "Start"** key is pressed.

The Record Trigger is set using **"F2"** on page 1 of the Trigger/Multimode menu. If Record Trigger is set to FREE–RUN, the data blocks are collected without other delay than the one specified. FREE–RUN is the only type of record trigger which allows overlap to be set.

3.4.3 Normal Multispectrum and Time Capture

Normal Multispectrum

Normal Multispectrum corresponds to the 2144's Normal Multispectrum mode. Fig. 3.2 illustrates the collection of a Normal Multispectrum. It applies to the collection of spectra (not time records) and shows only one channel.

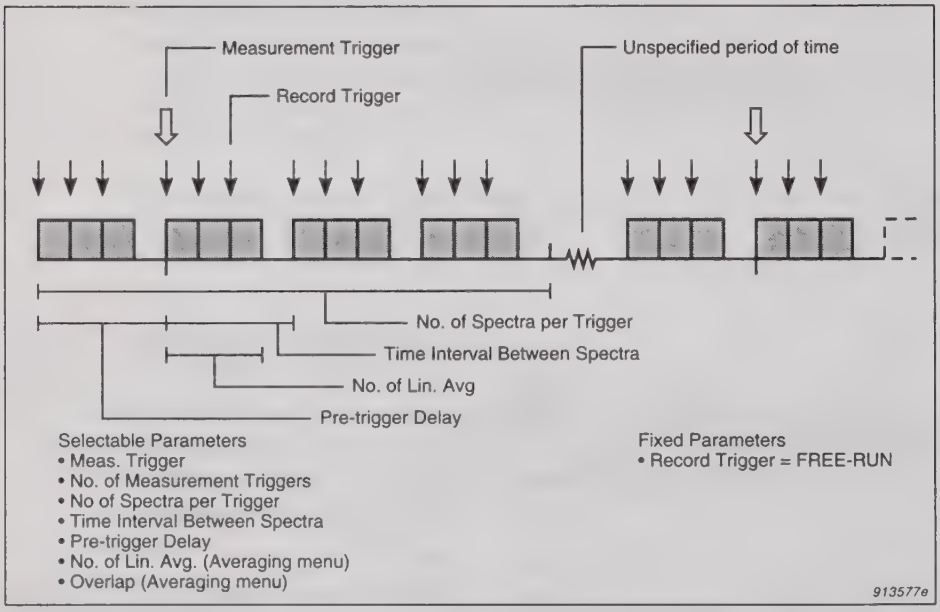

Fig. 3.2 Selectable parameters for data collection in Normal Multispectrum mode (pre-trigger delay shown)

The Record Trigger is always FREE–RUN in Normal Multispectrum mode.

The Measurement Trigger is defined on page 1 of the Trigger/Multimode menu. The total number of spectra in a multispectrum file is "No. of Spectra per Trigger" multiplied by "Number of Triggers".

Time Capture

Time Capture is similar to Normal Multispectrum, except that time records are collected instead of spectra. Fig. 3.3 illustrates the Time Capture principle. The figure shows only one channel.

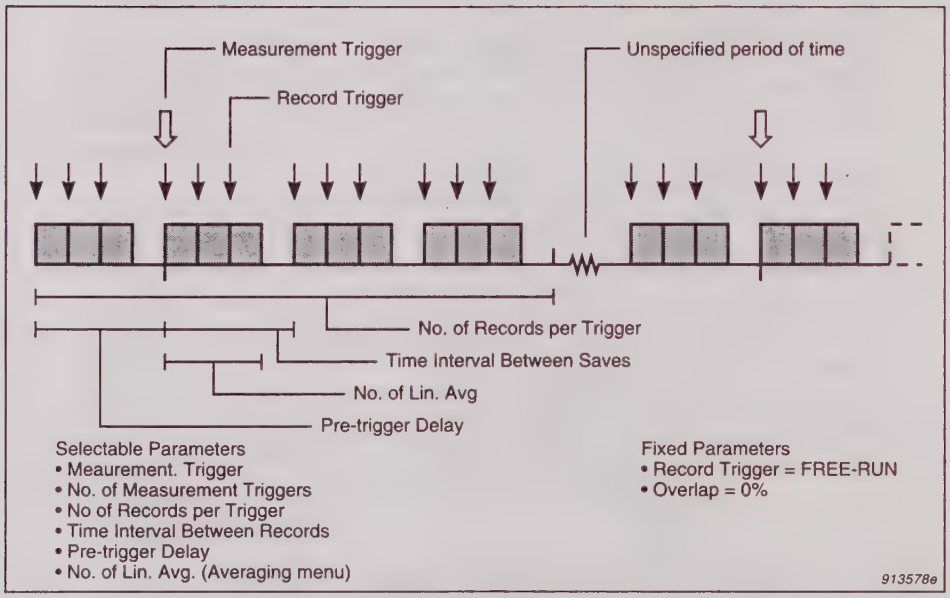

Fig. 3.3 Selectable parameters for data collection in Time Capture mode (pre-trigger delay shown)

The Record Trigger is always FREE–RUN in Time Capture mode and Overlap is always 0%.

The Measurement Trigger is defined on page 1 of the Trigger/Multimode menu. If the record length is equal to the linear averaging time and the time interval between saves (calculated on the left-hand side of the display), then one long time record is collected for each Measurement Trigger.

3.4.4 Gated Multispectrum

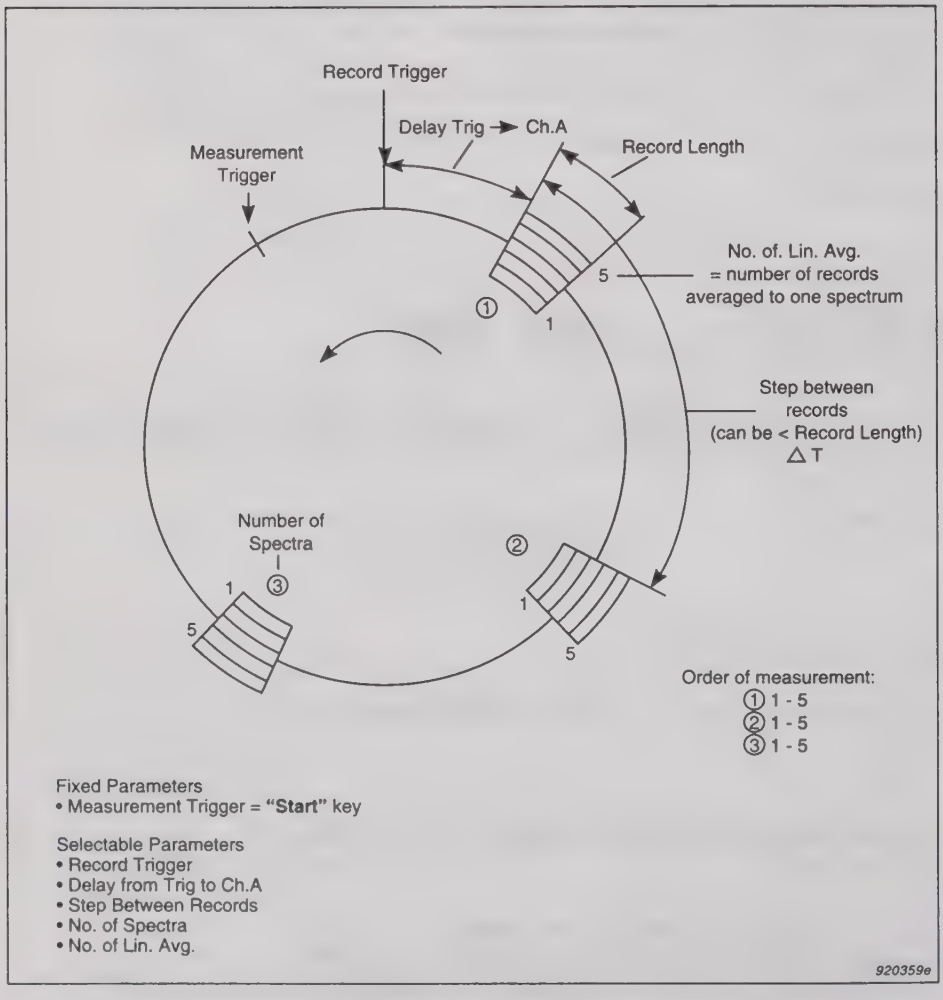

Fig. 3.4 Selectable parameters for data collection in Gated Multispectrum mode

Gated Multispectrum is intended for use in the investigation of the variation of measurement parameters as a function of position in a repetitive cycle. Fig. 3.4 illustrates the collection of a Gated

Multispectrum. The figure applies for collection of spectra and shows only one channel.

In Gated Multispectrum mode, the Measurement Trigger is always FREE–RUN. This means that the measurement starts when the **Averaging Control "Start"** key is pressed.

The Record Trigger is set using **"F2"** on page 1 of the Trigger/Multimode menu. Usually, an external trigger is needed, for example from a photoelectric probe, to obtain good accuracy of the trigger timing.

Suppose, for example, that the analyzer is set up to measure a gated multispectrum on a machine. Five linear averages are made at each of three positions in a machine cycle (Fig. 3.4). When **Averaging Control "Start"** is pressed, the analyzer waits for the first Record Trigger. A Record Trigger is needed for each of the 15 spectra. First, five spectra are measured for position ① and these spectra are averaged into the first spectrum in the gated multispectrum. Then the analyzer steps to position ② and averages all the spectra there before stepping to position ③ to measure and average the final five spectra. The result of the operation is a gated multispectrum consisting of three spectra.

Note: The maximimum number of spectra in the gated multispectrum is determined by the measurement type and by the number of lines. For example, if the analyzer is set up for single channel analysis, 400 lines, then the maximum number of spectra is 16.

3.4.5 Matrix Multispectrum

Matrix Multispectra are used to collect spectra in a row-column-direction matrix, especially sound intensity.

A Matrix Multispectrum is a Normal Multispectrum (for spectra) with the following fixed settings: No. of Spectra per Trigger = 1, Delay = 0. Record Trigger is FREE–RUN.

Measurement Trigger can be chosen freely, but is usually set to MANUAL for this type of measurement. The total number of Mea-

surement Triggers for a Matrix Multispectrum file is equal to Number of Rows × Number of Columns × Number of Directions.

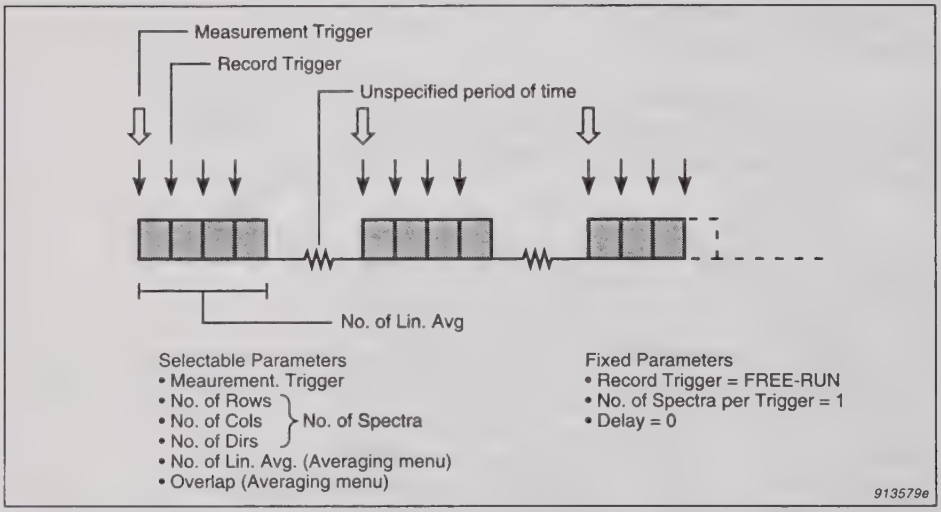

Fig. 3.5 Selectable parameters for data collection in Matrix Multispectrum mode

Fig. 3.5 illustrates the collection of a Matrix Multispectrum (one channel).

3.4.6 Internal Trigger and Peak Hold

Internal Trigger

In contrast to Type 2144, the trigger function of Type 7651 works in the time domain. The trigger is specified on page 6 of the Trigger/Multimode Menu, where you can enter a trigger value in dB or metric/imperial absolute units (default is metric) and specify triggering on positive or negative slope. A column on the left hand side of the screen shows the peak of the signal. To measure a new peak value, press **Averaging Control "Start"**. The peak value has no sign.

The trigger resolution is improved compared to Type 2144: it is 2ΔT in baseband and ΔT in zoom.

Peak Hold

The analyzer starts measuring when you enter the menu. When a peak hold measurement is started, the peak value of the input signal (after the input filters) is detected and held. The measurement can be restarted, paused and proceeded using **Averaging Control**.

3.4.7 External Trigger

The external trigger functions in the same way as for Type 2144 but the trigger resolution is improved. With Single and Gated and a delay from trigger to ch. A ≥ 0, it is 2ΔT in baseband and ΔT in zoom. Otherwise, the resolution is 1 ms.

3.5 Display Set-up

The Display Set-up menu corresponds to but is slightly different from the 2144's Display Modes menu in that the Display Set-up menu works with both frequency and time domains. The Y-axis can be labeled with dB or absolute units. With absolute selected and for charge input, you can choose between metric or imperial units. It is possible to apply a bow-tie correction to correlation calculations in the time domain (see section 4.6).

Units Philosophy

The 7651 allows you to select either relative (dB) or absolute units. If charge is selected in the Input menu, then absolute units can be further divided into metric or imperial. Imperial units are normally only used in the USA where m/s^2, m/s and m are replaced by g (9.81 m/s^2), inch/s and mil.

The philosophy for how metric and imperial units are used is described below for metric units. It is the same for imperial.

The units are displayed in the headline of the Measurement Mode screen. As spectrum units are chosen in the Display menu, some wrong combinations can occur, such as intensity measured in RMS.

In such cases, *** * * *** is shown instead of the actual unit. If a legal but unlikely combination such as the differentiation of m/s^2 to m/s^3 is chosen, then **unit** is written in the headline. If another transducer is used, for example a force transducer, the analyzer would normally display incorrect units (in this case m/s^2). To avoid this, the Display Set-up menus allow you to select **UNIT** directly.

Note: For Direct Input, the analyzer operates with Units rather than Volts.

3.6 Measurement Mode

Unlike the 2144, the Measurement Mode menu of the 7651 has submenus. Fig. 3.6 shows the Measurement Mode menu structure and also gives an overview of the functions controlled in each menu.

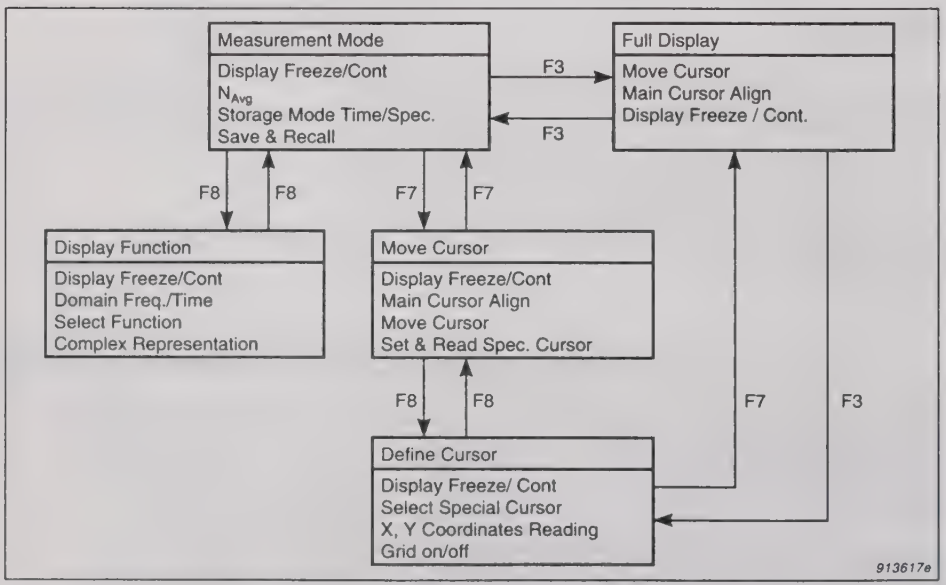

Fig. 3.6 Measurement Mode menu structure of Type 7651 showing the functions controlled from each menu

3.6.1 Display Information

The layout of the display is similar to that of the 2144. However, some of the status fields and the headline (see the 2144 User Guide) are different.

Status Fields

The status fields of the 7651 display are (top to bottom):

1. Overload percentages for channels A and B.
2. Analogue input filters for channels A and B. **HP** stands for high-pass filter followed by the lower 0.1 dB limit in Hz. **A** stands for A-weighting.
3. Trigger Mode. An empty field indicates that the Multispectrum Type in the Trigger/Multimode menu is SINGLE. **HOLD** indicates that Multispectrum Type is SINGLE and that the hold function specified in the Hold menu is active. **MULTI** indicates that Multispectrum Type is GATED, NORMAL or MATRIX.
4. In the frequency domain, **CORR** is displayed if the intensity correction is active, otherwise the field is empty. For a time-domain display, the field reads **BOW-T** if bow-tie correction is on (correlation only).
5. Zero padding. The field shows to which channel(s) zero padding is applied: **EMPTY** means no zero padding; **Z-PA**, **Z-PB** and **Z-PAB** mean zero padding of channel A, channel B, and both channels, respectively.
6. Time weighting functions for channels A and B, as specified in the Time Weighting Function menu.
7. Overlap percentage. Both channels use the same overlap. The field is empty if overlap information is not relevant.

Headline

The headline is mainly self-explanatory: only the last code needs explaining. The field gives information on whether the data is taken from input or memory and on the measurement type:

INA: Data from Input Module A, 1-channel analysis
INB: Data from Input Module B, 1-channel analysis

IND: Data from Input Modules A and B, 2-channel analysis
INX: Data from Input Modules A and B, cross analysis
RFD: Recalled data measured in the frequency domain
RTD: Recalled data measured in the time domain
CLC: Data which has been processed using the Spectrum Calculator menu

3.6.2 Display Functions

The **Display Func.** page (see Fig. 3.7) is used for selecting which functions to display. The functions are split up in two groups, one for the time domain and one for the frequency domain. **"F2"** is used to alternate between the two groups. The functions available (**"F3"** to **"F6"**) are closely related to the Measurement Types menu. Table 3.1 lists the available display functions for the different Measurement Types. Complex spectra, such as intensity, can be displayed as real part, imaginary part, magnitude or phase. Soft key **"F7"** is used to select these options.

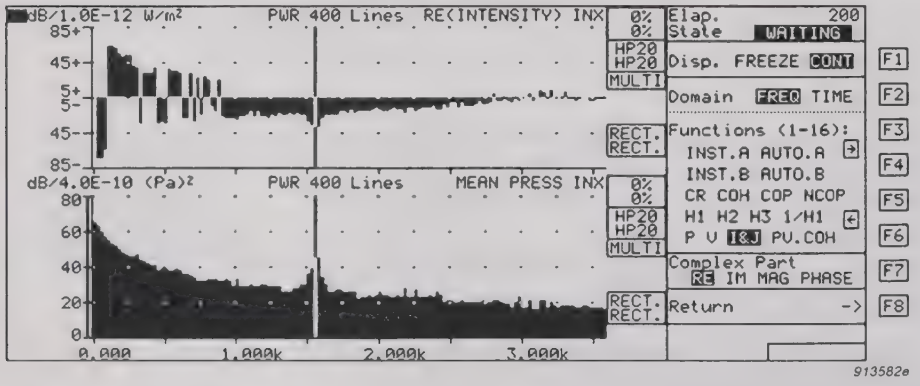

Fig. 3.7 Display Function page for which functions to display in Measurement Mode

Note: Display Functions only applies to what you see on the screen, not what is actually saved in the memory. For Single and Normal modes you can choose between saving data as spectra or time records (using **File Saving Mode** on pages 2 and 3

of the Trigger menu). For Gated and Matrix modes, data is always saved as spectra even though input data can be displayed in the time domain. This means that there are some limitations on which time domain functions can be displayed when data recorded in these modes is recalled.

Formulae

The display functions are calculated from the following formulae, where G_{AA} and G_{BB} are autospectra and G_{AB} is the complex cross-spectrum:

$$H1 = G_{AB}/G_{AA}$$

$$H2 = G_{BB}/G_{AB}$$

$$H3 = \frac{G_{AB}}{|G_{AB}|}\sqrt{\frac{G_{BB}}{G_{AA}}}$$

The coherence, γ, is calculated as

$$\gamma^2 = \frac{|G_{AB}|^2}{G_{AA} \cdot G_{BB}}$$

For intensity, γ_{pv} is given by

$$\gamma_{pv}^2 = \frac{I^2 + J^2}{p^2 v^2}$$

where I is the active intensity, J is the reactive intensity, p is the mean pressure $(p_A + p_B)/2$, and v is the particle velocity.

3.6.3 Cursor Functions

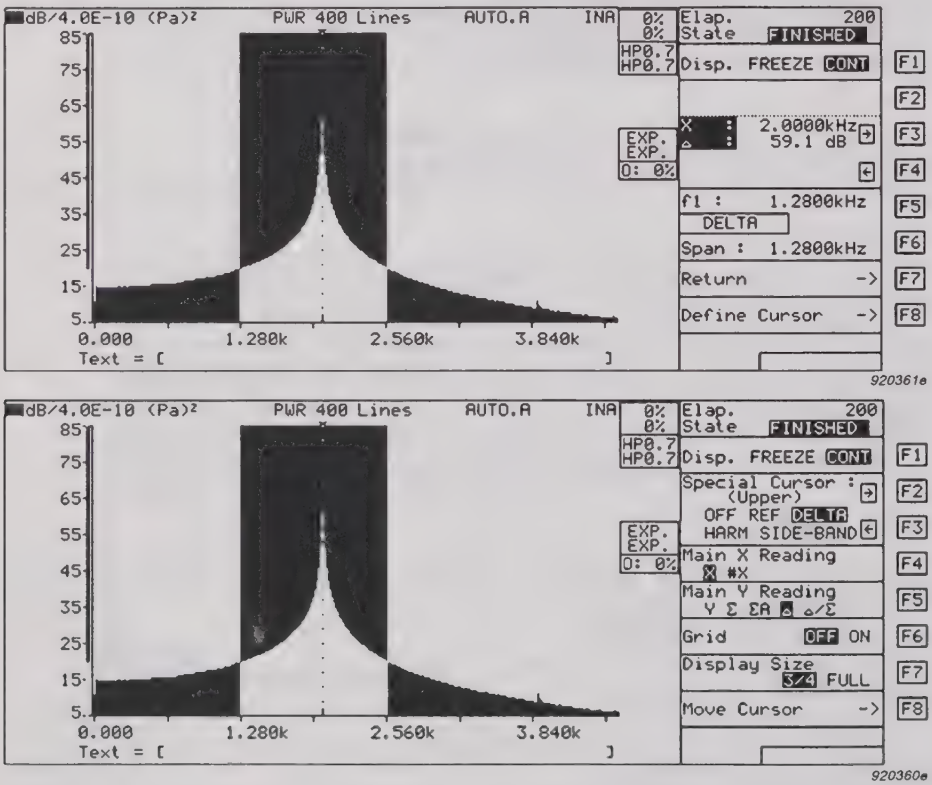

Fig. 3.8 Cursor Function submenus for controlling cursor movements and for selecting special cursors and cursor reading in Measurement Mode

Two pages in the Measurement Mode menu control the cursors.

The `Cursor Func.` (`Move Cursor`) page (Fig. 3.8, upper screen) is used for moving the main cursor to read the display values (**"F3"** and **"F4"**) and for aligning the main cursors of the upper and lower displays in Dual or Difference Display mode (**"F2"**). When the cursors are not aligned, the **"Upper/Lower"** key toggles the cursor control between the upper and lower displays. Another important function on this page is for setting of the special cursor parameter (**"F5"** and **"F6"**). These parameters change with the special cursor selected as explained in section 3.6.4.

The **Define Cursor** page (Fig. 3.8, lower screen) is for selecting which special cursor to display (**"F2"** and **"F3"**). The cursors are explained below. In the time domain, only the Reference Cursor is available.

Main Cursor

The Main Cursor is always displayed and, therefore, does not have to be selected. It is identified by a black triangle above the cursor line. The possible readings for the Main Cursor (when **Special Cursor** is **OFF**) are: **Y**, Σ or Σ**A** versus **X** or **#X** (see section 3.6.4).

Reference Cursor

When the Reference Cursor is selected, the Main Cursor Y-values are calculated and displayed relative to the Y-value at the Reference Cursor frequency or time, which is entered on the **Move Cursor** page in one of the following two ways:

a) Key-in a value for the Reference Cursor frequency or time and enter it by pressing **"F6"**.

b) Move the Main Cursor to the desired reference frequency or time and press **"F5"** to enter it as the Reference Cursor frequency or time.

The possible readings for the Reference Cursor are: **Y**, Δ**Y**, Σ or Σ**A** versus **X**, **#X**, or Δ**X** (see section 3.6.4).

Delta Cursor

The Delta Cursor is used for calculating power or energy in a part of a spectrum. The result of the calculation is read out on the **Move Cursor** page. The units for the value follow the setting of the Spectrum Unit (Display Set-up menu), which is also displayed in the Spectrum Header, in such a way that the sum over RMS and PWR do not change unit but ESD and PSD are converted to Energy and Power, respectively. The part of the spectrum or time record defined by the Delta Cursor is shown in inverse video. The delta-band is set on the **Move Cursor** page in one of the following two ways:

a) Move the Main Cursor to the start of the desired delta-band and press **"F5"**. Then key-in a numeric value for the frequency span and enter it by pressing **"F6"**.

b) Move the Main Cursor to the start/end of the desired delta-band and press **"F5"**. Then move the Main Cursor to the end/start of the desired delta-band and press **"F6"** (without keying-in a numeric value) to define the band.

The possible readings for the Delta Cursor are: **Y**, Σ, Σ**A**, Δ, or Δ/Σ versus **X** or **#X** (see section 3.6.4).

Harmonic Cursor

The Harmonic Cursor is used to identify harmonics in a spectrum where the fundamental frequency is known. The analyzer displays cursor lines for all higher harmonics. 64 harmonics can be shown, the first 16 of which are numbered. The fundamental frequency is set on the **Move Cursor** page in one of the following two ways:

a) Move the Main Cursor to the fundamental frequency and press **"F5"** to enter it.

b) Key-in a value for the fundamental frequency and enter it by pressing **"F6"**.

The possible readings for the Harmonic Cursor are: **Y**, Δ**Y**, Σ or Σ**A** versus **X**, **#X** or **#HRM** (see section 3.6.4).

Side-band Cursor

The Side-band Cursor is used for identifying possible spectral side-band effects of modulated signals. The analyzer displays one cursor line at the centre frequency with equidistant cursor lines on both sides. The Side-band Cursor is set on the **Move Cursor** page in the following way:

Move the Main Cursor to the centre frequency and press **"F5"**. Then key-in a numeric value for the nearest side-band frequency and enter it by pressing **"F6"** (the side-band frequency may be higher or lower than the centre frequency).

The possible readings for the Side-band Cursor are: **Y**, Δ**Y**, Σ or Σ**A** versus **X**, **#X** or **#SDB** (see section 3.6.4).

3.6.4 Cursor Readings

Display Options for X-values

"F4" on the `Define Cursor` page selects the type of X-coordinate readings. The options are:

- **X**: X-value as time or frequency
- **#X**: X-value as display line number
- **ΔX**: X-value as the difference in time or frequency between Reference Cursor and Main Cursor
- **#HRM**: Decimal value of harmonic number
- **#SDB**: Decimal value of side-band number

Display Options for Y-values

"F5" on the `Define Cursor` page selects the type of Y-axis reading. The options are:

- **Y**: Y-level or -value as defined in the Display Set-up menu
- **Σ**: Total power or energy across the entire frequency band or time record. Power is calculated if the Spectrum Unit is **PWR** or **PSD**, and energy if the Spectrum Unit is **ESD** (see the Display Set-up menu).
- **ΣA**: Same as Σ, but the spectrum is A-weighted.
- **ΔY**: **REF**: Main Cursor Y-value minus Reference Cursor Y-value; **HARM**: Main Cursor Y-value minus fundamental frequency Y-value; **SIDEBAND**: Main Cursor Y-value minus centre frequency Y-value
- **Δ**: RMS power or energy in the delta band
- **Δ/Σ**: RMS power or energy in the delta band divided by total RMS power or energy

Display Grid

The display grid is set to **OFF** as default to avoid interference with cursor lines. It can, if appropriate, be switched on by pressing **"F6"**.

Chapter 4

Special Functions

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4.1 No. of Lines

The transform size (and consequently the frequency resolution) is determined by the selection of Number of Lines in the Time/Freq Parameters menu. The number of lines in the FFT can be set to 50, 100, 200, 400 or 800 using **"F1"**. A setting of 400 lines, for example, gives a spectrum with 512 lines of which 401 (400 plus DC) are displayed. This corresponds to a transform size of 1024 samples.

Usually, selecting the frequency resolution is a compromise between speed and accuracy. For the 7651 it is, however, a matter of memory space since the spectrum recording rate is greater than 128 spectra per second, even for 400-line autospectra (1-channel). The number of autospectra or time records that the basic data memory (512 kb) can hold is shown in Table 4.1.

No. of Lines	No. of Spectra			No. of Time Records		
	1 ch.	2 ch.	Cross	1 ch.	2 ch.	Cross
50	504	336	201	336	201	201
100	336	210	112	201	112	112
200	201	112	59	112	59	59
400	112	59	30	59	30	30
800	59	30	15	30	15	15

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Table 4.1 Maximum numbers of spectra and time records in Data Memory as a function of Number of Lines for 1-ch, 2-ch and cross functions

If more memory is required, a memory extension to 2 Mb total, WH 2921, is available. With this extension, the number of spectra and time records is increased by a factor of approximately 13.

4.2 Baseband Analysis

In baseband analysis the upper frequency ranges from 0.7 Hz up to 25.6 kHz (both single and dual channel). The span can be stepped up or down in a binary sequence. Alternatively, you can step up or down the resolution, i.e. the line distance in Hz. The frequency reso-

lution is determined by the size of the transform, i.e. the number of lines, and is equal to Frequency Span divided by No. of Lines. The time resolution is $1/f_s$, where f_s is the sampling frequency. With baseband analysis, the frequency resolution is increased by increasing the transform size (No. of Lines) or decreasing the frequency span.

4.3 Zoom Analysis

There are certain situations where baseband analysis does not provide the resolution necessary to analyze a spectrum. It is, however, possible to increase the resolution over a specific portion of the spectrum (without increasing the transform size) by applying the Zoom function.

`Zoom` is set to `ON` by pressing **"F4"** in the Time/Freq Parameters menu. Type 7651 uses real-time zoom (as opposed to non-destructive zoom). The number of lines in the magnified portion of the spectrum is the same as that selected for the whole transform.

The zoom function has a centre frequency range from 4 Hz to 24.0 kHz (the limit set by the analog input module). For centre frequencies f_c from 4 Hz to 999 Hz, the frequency resolution Δf is at least 1 mHz. For $f_c \geq 1$ kHz, the minimum value of Δf is 100 mHz for single channel analysis, and 4 Hz for dual channel analysis in the range 12.5 kHz to 24.0 kHz.

Applying zoom to a spectrum reduces the dynamic range of the system in the vicinity of the zoom centre frequency. The reduction depends on the selected frequency span: the narrower span, the more reduction. Typically, the reduction is about 3 dB but is always < 7 dB, even in worst cases.

4.4 Time Weighting

Five time weighting functions ("time windows") can be selected in the Time Weighting Function menu which is found on page 2 of the Main menu. The weighting functions are: Rectangular, Hanning, Flat-Top, Transient, and Exponential. Transient and Exponential windows have selectable position and length.

In dual channel mode, different windows can be used on each input. For example, a flat or transient window can be used to measure a transient input signal on channel A while the exponential window is used to measure the system response on channel B.

4.5 Spectrum Weighting

Analogue A-weighting

An analogue A-weighting filter is selectable in the Input menu for probe, preamp., and direct inputs. This allows the analysis of signals which are A-weighted before FFT.

Digital A-weighting

Digital A-weighting can be applied to a spectrum just before it is shown on the display but it is not saved along with the measurement. It is selected as special cursor ΣA in Measurement Mode.

Digital A-weighting is also available on page 4 of the Spectrum Calculator menu.

4.6 Zero Padding and Bow-tie Correction

Zero padding and bow-tie correction are used to avoid circular folding in the calculation of correlation functions for continuous signals. The zero padding sets the second half of each time record to zero. The bow-tie correction is required to remove the ramp bias error caused by the zero padding (due to the decreasing amount of overlap between the two time records for increasing time shifts).

For transient signals (where the combined length of the A- and B-channel signals is shorter than one block of data) it is not necessary to use zero padding when calculating correlation functions. Note, however, that the bow-tie correction is never used without zero padding active.

Selecting Zero Padding and Bow-tie Correction

Zero padding is selected in the Time Weighting Function menu using **"F1"**. It can be applied to both input channels, simultaneously or individually. Default is **NONE**.

Bow-tie correction is specified for the upper and lower displays in the Display Set-up menu. It is only applicable to correlation functions in time domain, i.e. pages 3 and 5 of the Display Set-up menu. Bow-tie correction is set **ON** or **OFF** using **"F5"** on these pages. Default is **OFF**.

4.7 Data View

Cursor Facilities

The Data View menus allow the same cursor facilities as are available for Measurement Mode. These are described in section 3.5.

Overload Slice

Type 7651 allows three choices of x-axis: **FREQ** and **INDEX** are used in the same way as for Type 2144, **OVL** is new to the 7651 and displays an overload slice.

When you have measured and saved a multispectrum, and recall the file for display in the Data View menu, you can use **"F2"** to toggle the x-axis to display an overload slice, **OVL**. For each of the individual measurements in the multispectrum, the slice displays the percentage overload during that measurement.

"F3" and **"F4"** are used to select for whether the overload is to be displayed for channel A or channel B. **"F5"** and **"F6"** are used to select the index of a particular spectrum in the multispectrum. The Y-value for that index, expressed as a percentage, can then be read from the box between F4 and F5.

Note: If you have measured, for example, a $4 \times 4 \times 1$ matrix multispectrum, the indices of the slice will range from 1 to 16 and will always be in the same order as which you measured the multispectrum. It is therefore important to remember whether you have measured row, column, direction; column, row, direction; etc.

4.8 Spectrum Calculation

The Spectrum Calculator menus of Type 7651 combine the Spectrum Calculator and Spectrum Weighting menus of Type 2144. Since operations using these menus are almost the same as for Type 2144, only the main differences are detailed here.

Reset Buffer

As long as transform size, frequency parameters, sampling frequency, etc. are the same for a number of files, any of these files can be recalled on page 4 of the menu. If however, you want to recall a file with different parameters, you will first have to go to page 3, press **"F2"** `Reset Buffer`, and then return to page 4 to recall the file.

Weighting

Page 4 of the Spectrum Calculator menu allows you to select and add a weighting to the upper recalled curve. **"F3"** selects the type of weighting to be added, and **"F4"** adds the weighting. Four user-definable weightings U1 to U4 can be selected, as well as A^{-1}-, A-, B-, C-, D- and L-weighting. If L-weighting is selected, you can enter a constant to be added to the entire spectrum.

Recalling Weightings

Once you have created and saved a weighting (Spectrum Calculator page 5), you can recall it by entering its number (1 to 4) from the numerical keypad and pressing **"F6"**. Entering the number 0 clears the editing buffer.

Chapter 5

Interface

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5.1 Introduction

This chapter is intended as a supplement to Vol. 2 of the 2144 User Guide, Interface. It contains information about the interface messages for Type 7651. Only the interface messages which are new to Type 7651, or which replace already existing messages for Type 2144 are described here. The information in Chapters 1, 2, 3, 4, 9 and 10 of the 2144 User Guide also applies to Type 7651 and is therefore not repeated.

5.2 Set-up Messages

5.2.1 Measurement_Type (M_T)

Replaces section 6.1 of the 2144 User Guide, Vol. 2. The command message is used to set the **M_T** data field and display the Measurement Type menu. The query message returns a readout of the current setting of the **M_T** data field.

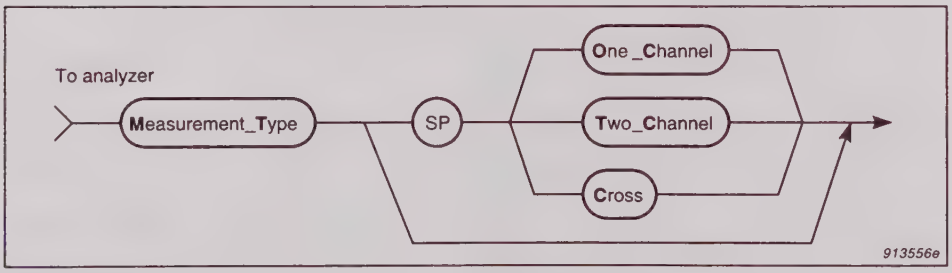

*Fig. 5.1(a) Syntax for the **M_T** command message*

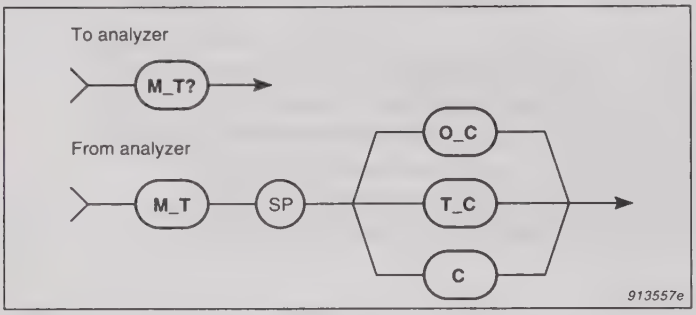

*Fig. 5.1(b) Syntax for the **M_T?** query message and analyzer response*

5.2.2 INput (IN)

Replaces section 6.2 of the 2144 User Guide, Vol. 2. The command message is used to set the **IN** data field and display the Input menu. The query message returns a readout of the current **IN** data fields. The data fields and their settings are listed in Table 5.1

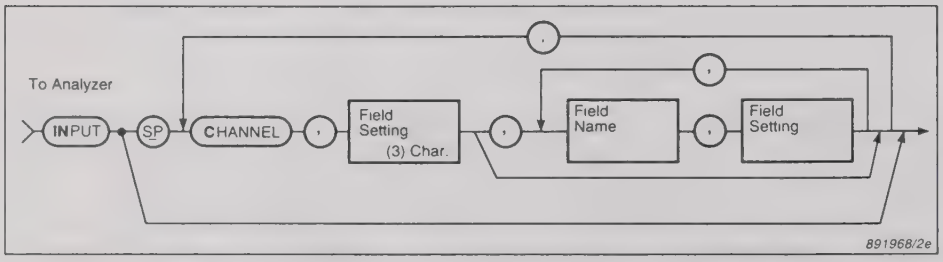

*Fig. 5.2(a) Syntax for the **IN** command message*

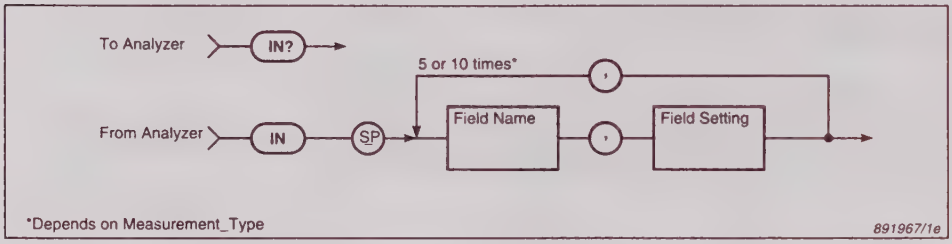

*Fig. 5.2(b) Syntax for the **IN?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Channel	**A_C** **B_C** **A_B**	Char.	Cross mode only
Type_Of_Input	**P**robepreamp **D**irect **C**harge	Char.	Not with **A_W**eighting①
Filter	**H**igh_Pass_**0.3** **H**igh_Pass_**0.7** **H**igh_Pass_**20** **H**igh_Pass_**100** **A_W**eighting	Char.	Not with Charge
Low_Pass	**ON** **OF**f	Char.	Only with Charge
Max_Input	<numeric>	NR 1/3② with suffix③	
Input_Protection	**ON** **OF**f	Char.	
DC_Compensation	**ON** **OF**f	Char.	

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① It is recommended to set the Filter setting before setting the Type_Of_Input.
② Depends on whether Y-axis unit is dB or Absolute
③ When the suffix unit is dB or Absolute, Max Input is independent of the Y-axis unit

*Table 5.1 **IN**put data fields and codes*

5.2.3 Time_Freq_Parameters (T_F_P)

New to Type 7651. The command message is used to set one or more specified **T_F_P** data fields and to display the Time/Frequency Parameters menu. The query message returns a readout of the current **T_F_P** data fields. The data fields and their settings are listed in Table 5.2.

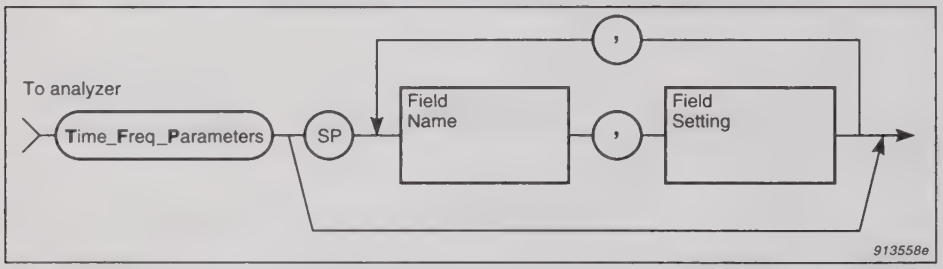

*Fig. 5.3(a) Syntax for the **T_F_P** command message*

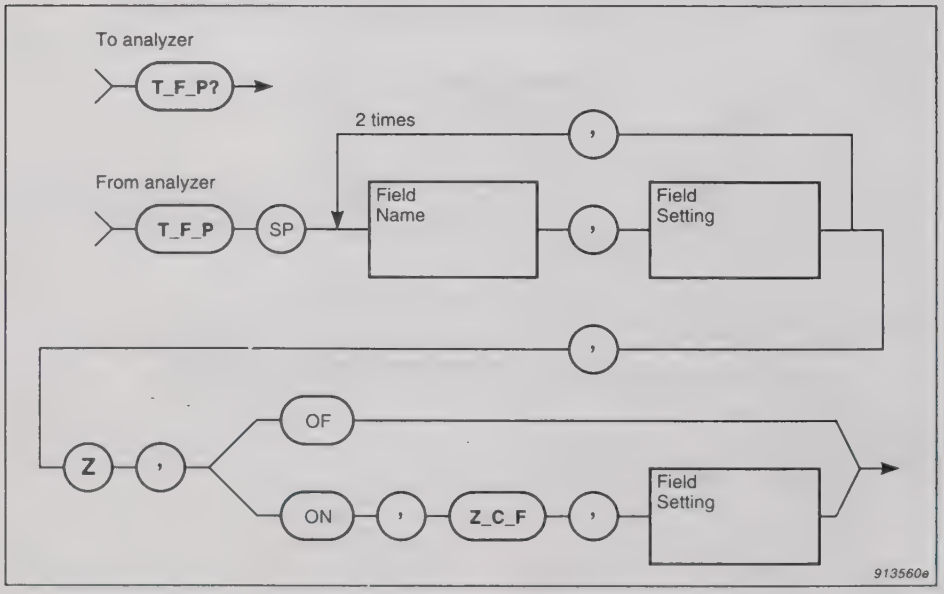

*Fig. 5.3(b) Syntax for the **T_F_P?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Numberof_Lines	50;100;200; 400;800	NR1	
Frequency_Span	<numeric>	NR3 (with suffix)	
Xaxis Sequence_Select	Resolution Span	Char.	
Zoom	OFf ON	Char.	
Zoom_Center_Freq	<numeric>	NR3 (with suffix)	Only with Zoom on

Table 5.2 Time_Freq_Parameters data fields and codes T03487GB0

5.2.4 CAlibration (CA)

Replaces section 6.4 of the 2144 User Guide, Vol. 2. The command message is used to set one or more specified **CA** data fields and display the Calibration menu. The query message returns a readout of the current **CA** data fields for all inputs (with the exception of Auto_Calibration). The data fields and their settings are listed in Table 5.3.

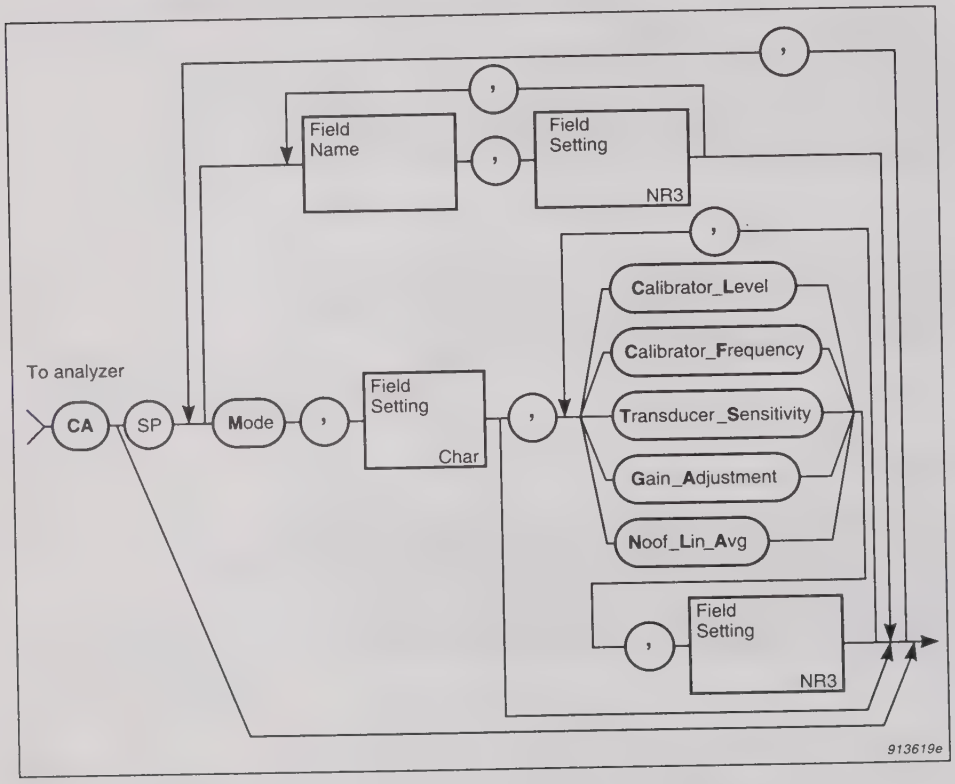

Fig. 5.4(a) Syntax for the ***CA*** *command message*

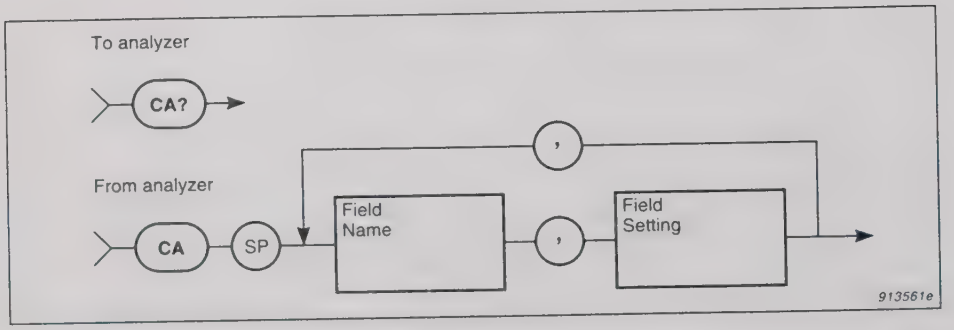

Fig. 5.4(b) Syntax for the ***CA?*** *query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Reference	**A** **B** **Re_Im** **V** **I_J**	Char.	Cross mode only
User_Reference		NR3	
Nominal_Spacing		NR1	
Ambient_Temperature	–25 to 100	NR2	Degrees Celcius
Ambient_Pressure	650 to 1100	NR1	Default unit hPa
Air_Density		NR3 (with suffix)	Default unit kg/m^3
User_Density		NR3 (with suffix)	Default unit kg/m^3
Mode	**A** **B** **A_B** **I** **V**	Char.	1-ch } 2-ch } Cross I and V only for verification of intensity calibration
Calibrator_Level		NR3	See note in the Input message for Max_Input
Calibrator_Frequency		NR3	
Transducer_Sensitivity		NR3	
Gain_Adjustment		NR3	See note in the Input message for Max_Input
Noof_Lin_Avg	128;256; 512;1024	NR1	
Auto_Calibration	Start	Char.	Input only
Auto_Verification	Start	Char.	Input only

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*Table 5.3 **CA**libration data fields and codes*

5.2.5 COrrection (CO)

Replaces section 6.5 of the 2144 User Guide, Vol. 2. The command message is used to set one or more specified **CO** data fields and display the Correction menu. The query message returns a readout of the current **CO** data fields. The data fields and their settings are listed in Table 5.4.

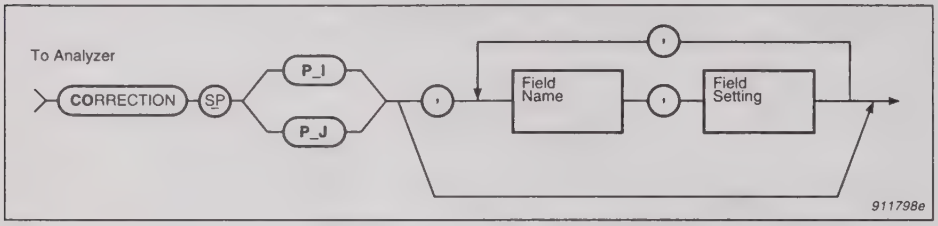

*Fig. 5.5(a) Syntax for the **CO** command message*

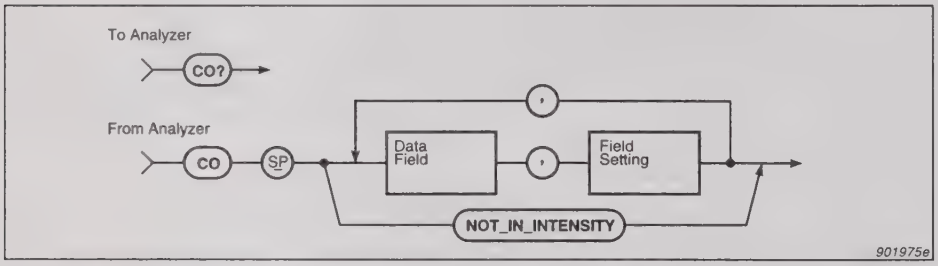

*Fig. 5.5(b) Syntax for the **CO?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Range_High_Freq		NR3	
Range_Low_Freq		NR3	
Noof_Averages		NR1	
Correction	**ON** **OFf**	Char.	
Save_Correction	1–999		Input message only

T03493GB0

*Table 5.4 **COrrection** data fields and codes*

5.2.6 AVeraging (AV)

Replaces section 6.6 of the 2144 User Guide, Vol. 2. The command message is used to set one or more specified **AV** data fields and display the Averaging/Channel Delay menu. The query message returns a readout of the current **AV** data fields. The data fields and their settings are listed in Table 5.5.

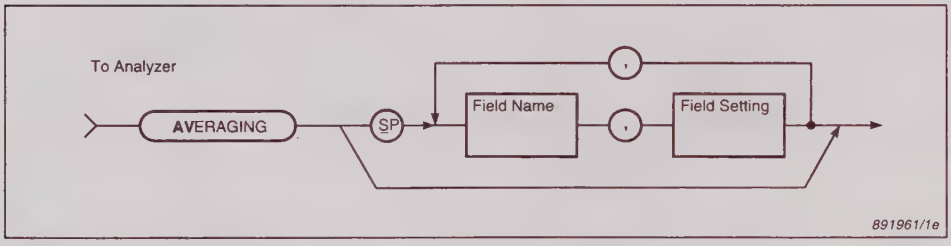

*Fig. 5.6(a) Syntax for the **AV** command message*

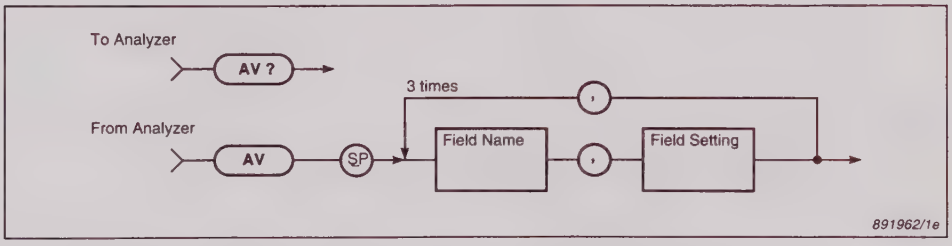

*Fig. 5.6(b) Syntax for the **AV?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Average_Mode	Linear Exponential	Char.	
Numberof_Averages		NR1	
Free_Run_Overlap	0;50;67;75 Max	NR1 Char.	Percent
Delayfromch_Atoch_B		NR3	
Overload_Reject	ON OFf	Char.	
Reject_Hysteresis		NR1	
Auto_Range_Time		NR3	

T03501GB0

Table 5.5 AVeraging data fields and codes

5.2.7 Display_Set_Up (D_S_U)

New to Type 7651. The command message is used to set one or more specified **D_S_U** data fields and to display the Display Set-up menu. The query message returns a readout of the current **D_S_U** data fields. The data fields and their settings are listed in Table 5.6.

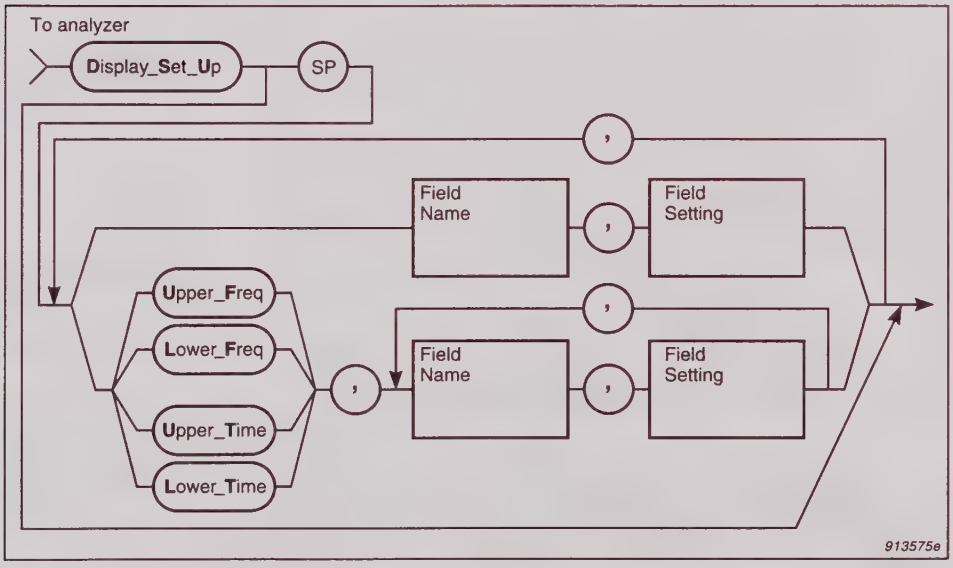

*Fig. 5.7(a) Syntax for the **D_S_U** command message*

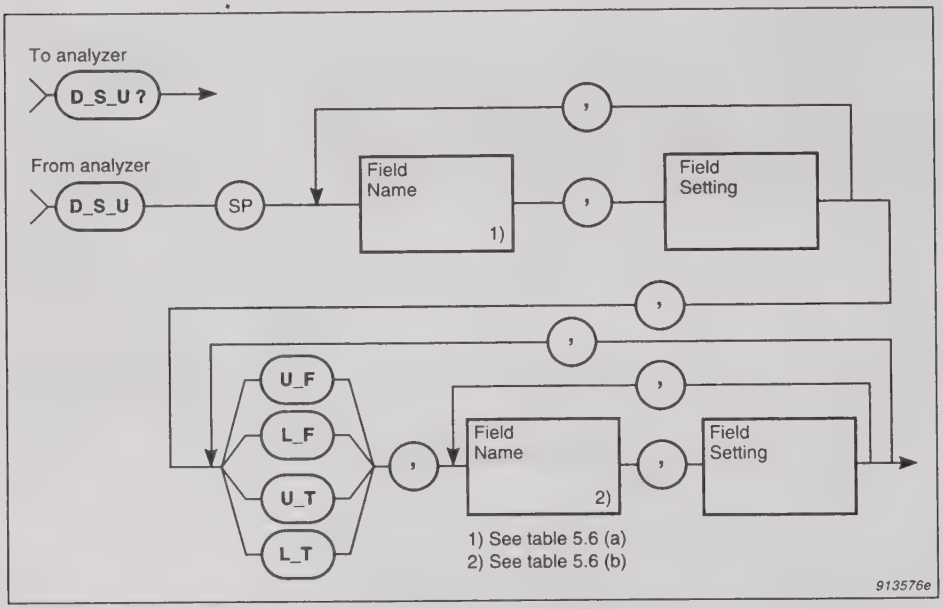

*Fig. 5.7(b) Syntax for the **D_S_U?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Mode_**O**ptions	**S**ingle **DU**al **DI**fference	Char.	
Freqdomain_**Y**_**A**xis	**A**bsolute **DB**	Char.	
Timedomain_**Y**_**A**xis	Linear **A**bsolute **DB**	Char.	
Y_**A**xis_**U**nit	**M**etric **IM**perial	Char.	
Freq_**A**xis_**C**ompression	**ON** **OF**f	Char.	
Time_**A**xis_**C**ompression	**ON** **OF**f	Char.	
Unitin_**H**eadline	**DE**fault **U**nit	Char.	

T03502GB0

*Table 5.6(a) **Display_Set_Up** data fields and codes*

Field Name	Field Setting	Data Type	Comments
Full_Scale	<numeric>	NR3	①
DISplayed_**A**mplitude_ **R**ange	10;20;40; 80;160	NR1	Always in dB Only Freq.
Spectrum_**U**nit	**PWr** **R**ms **PS**d **E**sd	Char.	Only Freq.
Differentiationor_ Integration	**D**iff_Twice **DI**fferentiated **N**one **IN**tegrated Integrated_Twice	Char.	Only Freq.
Bowtie_**C**orrection	**ON** **OF**f	Char.	Only Time
Displayed_**P**hase_ **R**ange	0.2;1;5;45; 90;180;360	NR1/NR2	
Displayed_**R**ange_**LO**g	10;20;40; 80;160	NR1	Only Time Always in dB
Displayed_**R**ange_**LI**n	1.6;3.2;6.3;12.5; 25;50;100	NR1/NR2	Only Time
DIFference_**A**mpl_ **R**ange	1;5;10;20;40; 80;160	NR1	Only Freq. Always in dB Only for Upper

T03503GB0

① See Note in the INput message for Max Input

*Table 5.6(b) **D**isplay_**S**et_**U**p data fields and codes (continued)*

5.2.8 Hold (H)

Replaces section 6.8 of the 2144 User Guide, Vol. 2. The command message is used to set one or more specified **H** data fields and display the Hold menu. The query message returns a readout of the current **H** data fields. The data fields and their settings are listed in Table 5.7.

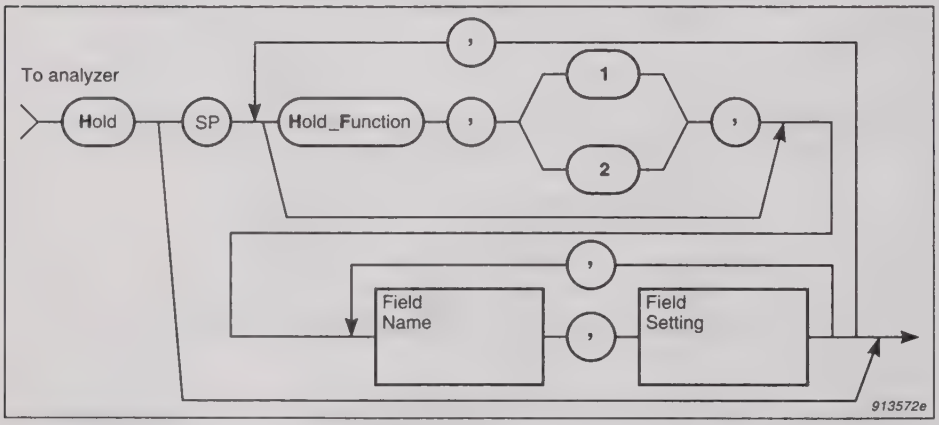

*Fig. 5.8(a) Syntax for the **H** command message*

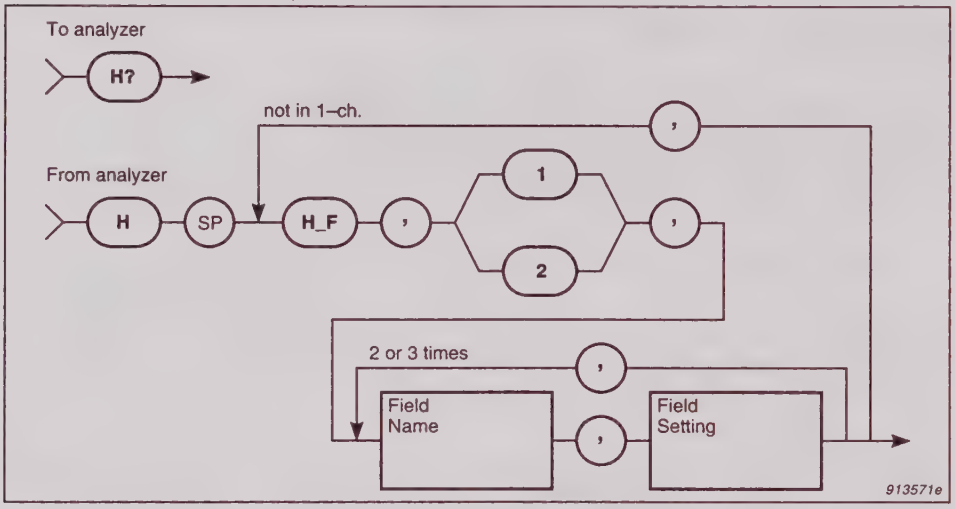

*Fig. 5.8(b) Syntax for the **H?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Hold_Function	1 or 2	NR1	Ignored in 1-ch.
Type	**MAx** **MIn**	Char.	
Spectrum	**A**uto_**A** **A**uto_**B** **C**ross_**R**e **C**ross_**I**m	Char.	Ignored in 1-ch. }Cross only
MOde	Inactive **A**ll **L**ine	Char.	
Line_Frequency		NR3 (with suffix)	Only in Line MOde

T03504GB0

*Table 5.7 **H**old data fields and codes*

5.2.9 Time_Weight_Function (T_W_F)

New to Type 7651. The command message is used to set the **T_W_F** data fields and display the Time Weighting Function menu. The query message returns a readout of the current **T_W_F** data fields. The data fields and their settings are listed in Table 5.8.

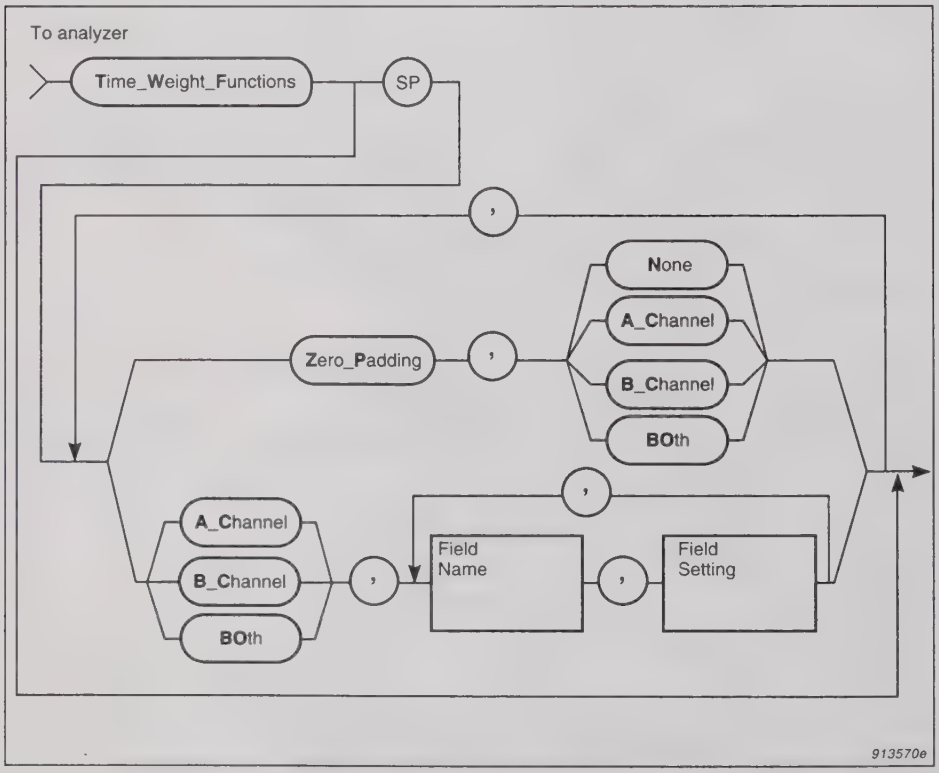

*Fig. 5.9(a) Syntax for the **T_W_F** command message*

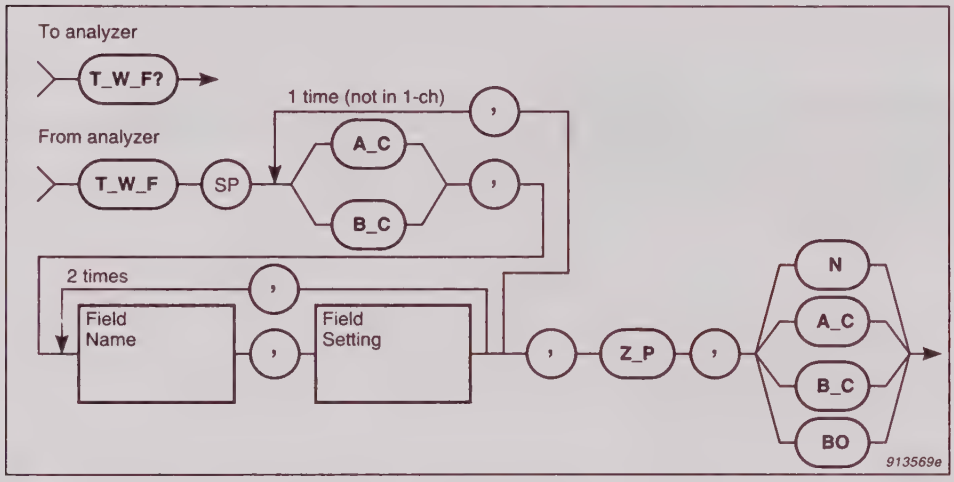

*Fig. 5.9(b) Syntax for the **T_W_F?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Zero_Padding	None A_Channel B_Channel BOth	Char.	 Only 2-ch & Cross
Weighting	Rectangle Hanning Flattop Transient Exponential	Char.	
Window_Shift	<numeric>	NR3	Only Transient and Exponential
Window_Length	<numeric>	NR3	Only Transient and Exponential

T03505GB0

*Table 5.8 **Time_Weight_Function** data fields and codes*

5.2.10 Trigger (T)

Replaces section 6.15 of the 2144 User Guide, Vol. 2. The command message is used to set one or more specified **T** data fields and to display the Trigger/Multimode menu. The query message returns a readout of the current **T** data fields. The data fields and their settings are listed in Table 5.9.

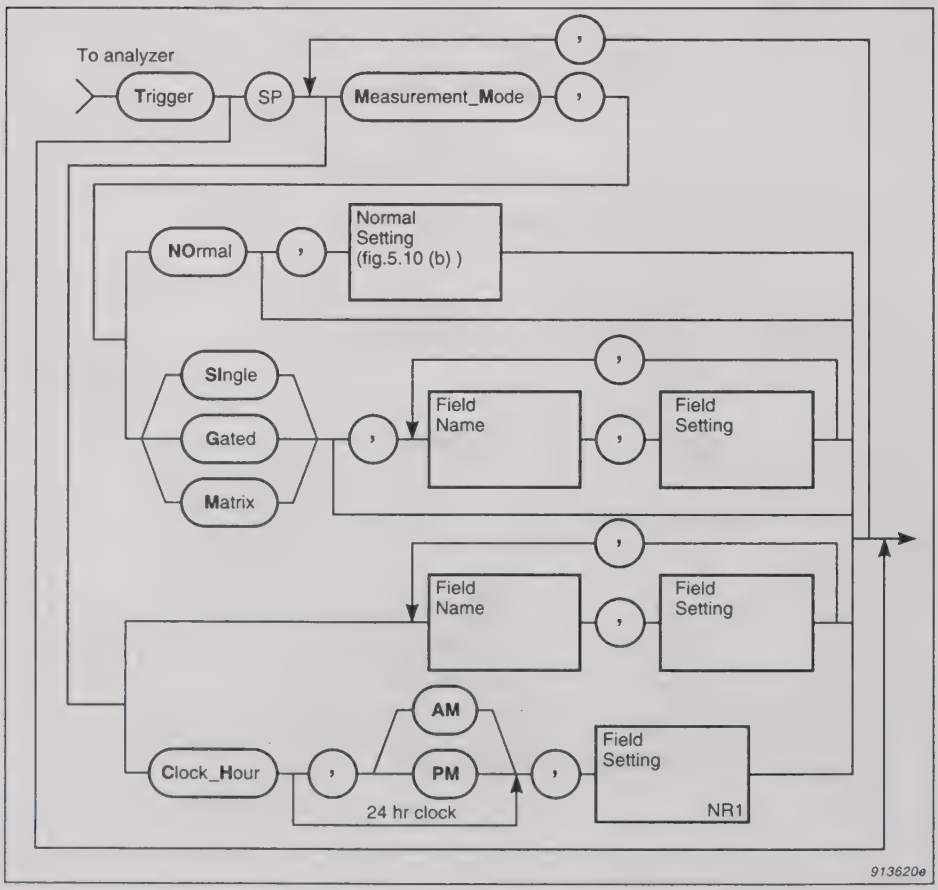

*Fig. 5.10(a) Syntax for the **T** command message*

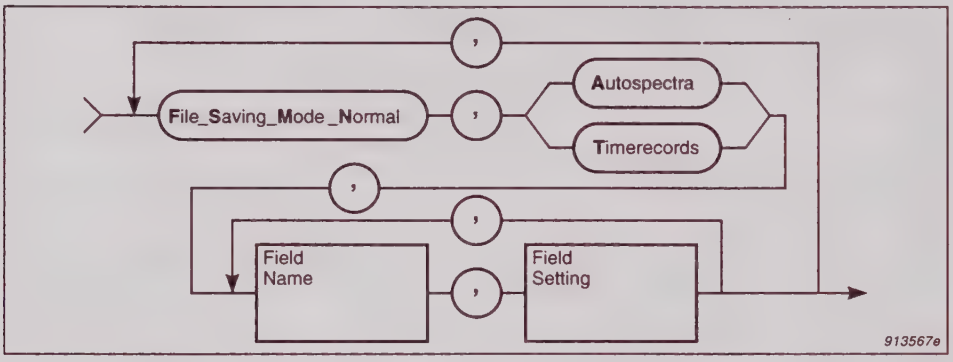

Fig. 5.10(b) Syntax for the Normal setting

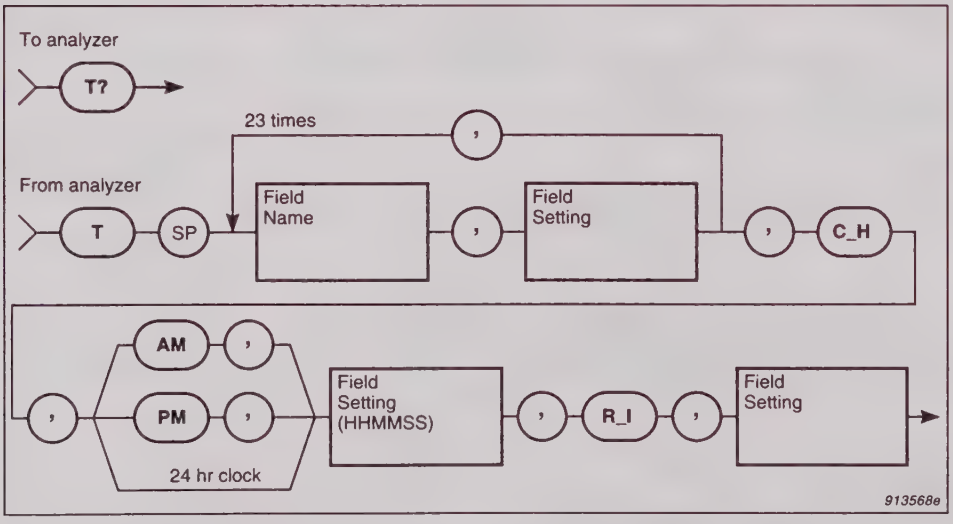

*Fig. 5.10(c) Syntax for the **T?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Measurement_Mode	**SI**ngle **G**ated **NO**rmal **M**atrix	Char.	
Trigger_**SE**lect	Internal **E**xternal **CL**ock **M**anual Free_**R**un	Char.	
Trigger_Value	<numeric>	NR3	①
Trigger_**SL**ope	**PO**sitive **NE**gative	Char.	
Clock_Hour	**AM**, <integer> **PM**, <integer> <integer>	Char. NR1	HHMMSS Integer only Defaults to 24 hr clock
Repetition_Interval	<numeric> **MI**n <numeric> **S**ec	NR2 (with suffix)	Default is seconds

T03509GB0

① See Note in the INput message for Max Input

*Table 5.9(a) **T**rigger data fields and codes*

Field Name	Field Setting	Data Type	Comments
Data fields and codes for Single Measurement			
Delayfrom_Triggerto_ Channel_Single		NR3	Seconds
File_Saving_ Mode_Single	**AU**tospectra **T**imerecords	Char.	
Data fields and codes for Gated Measurement			
Delayfrom_Triggerto_ Channel_Gated		NR3	Seconds
Stepbetween_**RE**cords		NR3	Seconds
Numberof_Spectra		NR1	

T03510GB0

*Table 5.9(b) **T**rigger data fields and codes for Single and Stepped modes*

Field Name	Field Setting	Data Type	Comments
Data fields and codes for Normal Measurement			
File_Saving_Mode_Normal	**AU**tospectra Timerecords	Char.	
Time_Delay_Autospectra		NR3	A negative value = pretriggering
Numberof_Spectraper_Trigger		NR1	
Time_Interval_Between_ Spectra		NR3	
Numberof_Triggers_ Autospectra		NR1	
Time_Delay_Timerecords		NR3	A negative value = pretriggering
Numberof_Recordsper Trigger		NR1	
Time_Interval_Between_ Records		NR3	
Numberof_Triggers_ Timerecords		NR1	
Data fields and codes for Matrix Measurement			
Numberof_Rows	1 to 99	NR1	
Numberof_Columns	1 to 99	NR1	
Numberof_Directions	1 to 3	NR1	
Measurement_Sequence	**DCR** **DRC** **CDR** **CRD** **RDC** **RCD**	Char.	
Spacebetween_ROws		NR3	Default is mm
Spacebetween_Columns		NR3	Default is mm

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*Table 5.9(c) **T**rigger data fields and codes for Normal and Matrix modes*

5.3 Device Control Messages

This section corresponds to Chapter 7 of the 2144 User Guide, Vol. 2. All Device Control Messages are identical to those of the 2144 with the following exceptions.

5.3.1 IDentify? (ID?)

Replaces section 7.5 of the 2144 User Guide, Vol. 2. The **IDentify?** message (query only) returns a readout of the instrument type. If version B of the message is sent, then the input module identification (analogue type) and the software version number are also returned.

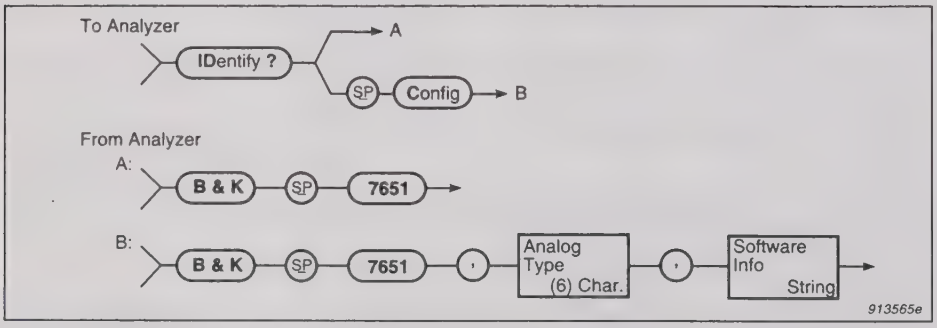

*Fig. 5.11 Syntax for the **ID?** query message and analyzer response*

5.3.2 Measurement_Mode (M_M)

Replaces section 7.10 of the 2144 User Guide, Vol. 2. The command message is used to set one or more specified **M_M** data fields and to display the Measurement Mode menu. The query message returns a readout of the current **M_M** data fields. The command data fields and their settings are listed in Table 5.10(a) to (c). The query returns a readout of all the data fields listed in Table 5.10(d) together with their actual settings.

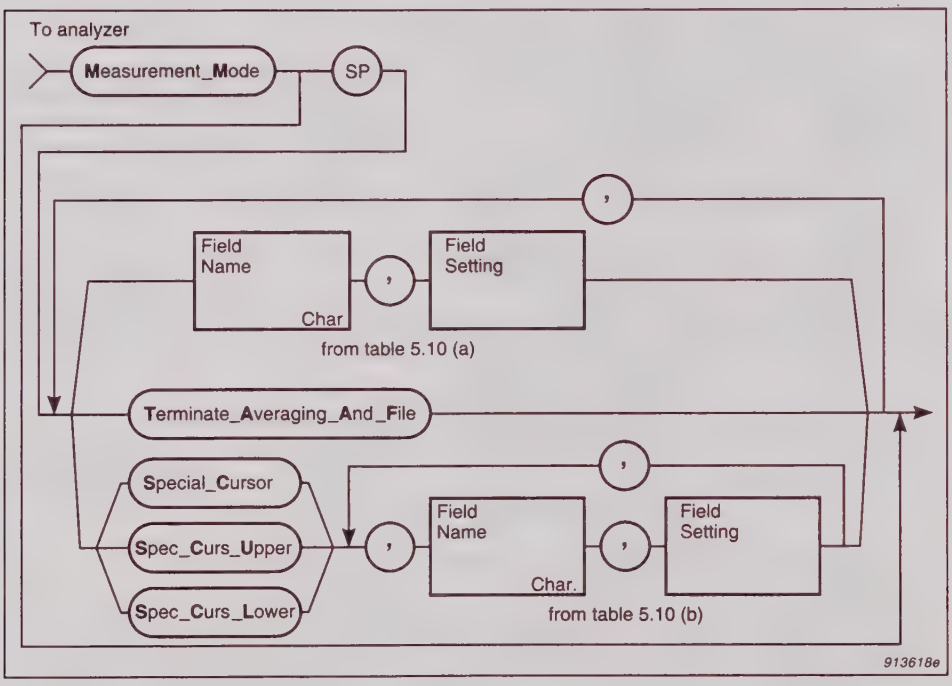

*Fig. 5.12(a) Syntax for the **M_M** command message*

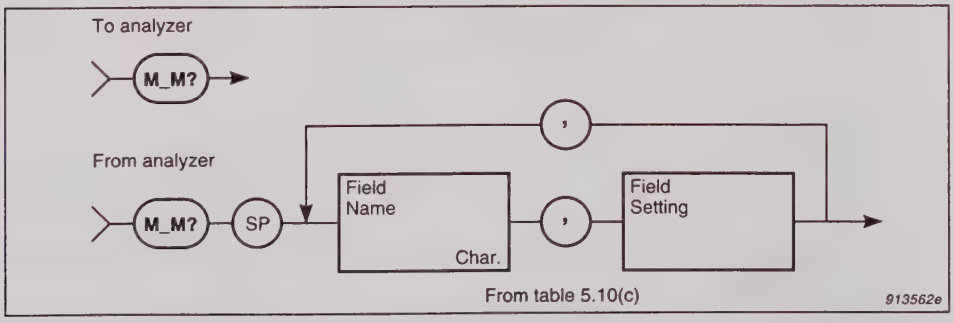

*Fig. 5.12(b) Syntax for the **M_M?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
DIsplay	**FREE**ze **CON**tinue	Char.	
No_Of_Average	1 – 32767	NR1	
Display_Size	Three_Quarters **FU**ll	Char.	
Storage_Mode	**TI**me **AU**to_Cross	Char.	Only in Single
Terminate_Averaging_And_File	[none] (not a setting)		Only in Normal or Matrix
Monitor_Spectrum_No	1 – 999	NR1	Only in Gated
SAve	1 – 999	NR1	Only in Single or Gated
Open_File	1 – 999	NR1	Only in Normal or Matrix
RECall Recallto_Upper Recallto_Lower	1.001 – 999.999	NR1 NR2	For Multispectrum
Display_Domain	**FREQ** **TI**me	Char.	
Display_Function Display_Function_Upper Display_Function_Lower	Instant_A Instant_B Auto_A Auto_B **CR**oss **COH**erence **COP** Ncop H1 H2 H3 Reciprocal_H1 **PR**essure Velocity I_J Pv_Coh Time_Record_A Time_Record_B Correl_AA Correl_BB Correl_AB Impulse_Response		Frequency Domain (Hz) Time Domain (s)

T03512GB0

*Table 5.10(a) **M**easurement_**M**ode data fields and settings (command)*

Field Name	Field Setting	Data Type	Comments
Display_Complex_Part_ Upper Display_Complex_Part_ Lower	**REAL** **IM**aginary **MA**gnitude **PH**ase		Must be set *after* Display_Function①
ALign_Cursor	**ON** **OF**f	Char.	
Cursor_Position Cursor_Position_Upper Cursor_Position_Lower		NR3	Hz or seconds for Freq/Time
GRid	**ON** **OF**f	Char.	
Y_Reading **Y_R**eading_**U**pper **Y_R**eading_**L**ower	Line_Value **TO**tal Total_**A** **D**elta_**Y** Sum_**S**pan Sum_Span_ **D**iv_Total	Char.	Not Delta } Only Delta } Only Spec_Curs.

T03513GB0

① There exists one Complex_Part for each Display_Function (if relevant).
Changing Display_Function therefore recalls the Complex_Part (if any) previously used with the new Display_Function

*Table 5.10(b) **M**easurement_**M**ode data fields and settings (command)*

Field Name	Field Setting	Data Type	Comments
Special_Cursor_Function	**OF**f **REF**erence **DE**lta **HA**rmonic Side_**B**and	Char.	} Not for time domain
Special_Cursor_Span ①	<numeric>	NR3	For Delta or Side_band cursor
Special_Cursor_Position ①	<numeric>	NR3	For Ref or Harmonic cursor

T03514GB0

① In Hz for frequency domain and in seconds for time domain.

*Table 5.10(c) **M**easurement_**M**ode data fields and settings for special cursors (command)*

Field Name	Field Setting	Data Type	Comments
Averaging_**S**tatus	**U**ndef **READ**y **RU**nning **PA**used **FI**nished **W**aiting **SE**ttling **GA**thering **A**uto_**R**ange		This field can also be read out using the Acutual_ Status message.
DIsplay **D**isplay_**U**pper **D**isplay_**L**ower	**FREE**ze **CON**tinue	Char.	
SAve ①		NR1	
ALign_**C**ursor	**ON** **OF**f	Char.	
Display_**D**omain	**FREQ** **TI**me	Char.	

T03520GB0

① This is the figure displayed after 'SAVE IN' on the screen of the analyzer

*Table 5.10(d) **M**easurement_**M**ode? data fields and settings (query)*

Field Name	Field Setting	Data Type	Comments
Display_Function_Upper Display_Dunction_Lower	Instant_A Instant_B Auto_A Auto_B CRoss COHerence COP Ncop H1 H2 H3 Reciprocal H1 PRessure Velocity I_J Pv_Coh Time_Record_A Time_Record_B Correl_AA Correl_BB Correl_AB Impulse_Response		
Display_Complex_Part_ Upper Display_Complex_Part_ Lower	REAL IMaginary MAgnitude PHase		
Averaging_Elapsed		NR1	

T03517GB0

Table 5.10(d) continued

5.4 Status, Result and Display Messages

This section corresponds to Chapter 8 of the 2144 User Guide, Vol. 2. All Status, Result and Display Messages are identical to those of the 2144 with the following exceptions.

5.4.1 Actual_Status?

Replaces section 8.3 of the 2144 User Guide, Vol. 2. **Actual_Status?** (query only) returns a readout of the status of one of the three **A_S** data fields, as listed in Table 5.11.

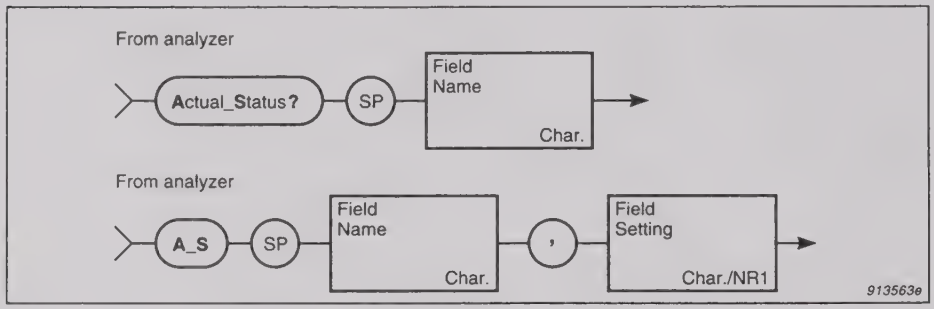

*Fig. 5.13 Syntax for the **A_S?** message*

Field Name	Field Setting	Data Type	Comments
Averaging	**U**ndef **READ**y **RU**nning **PA**used **FI**nished **W**aiting **SE**ttling **GA**thering **A**uto_**R**ange	Char.	
Input_Overload		NR1	8-bits status Bit 1 (LSB) Common Bit 2 Channel A Bit 3 Channel B Bit 4-8 Not Used
Global_Warning	**L**ow_**P**ower **I**nput_**P**otection **N**one	Char.	

T03516GB0

Table 5.11 Actual_Status? data fields and codes

5.4.2 Measurement_Data_Transfer (M_D_T)

New to Type 7651. The **M_D_T** command and query messages are used to load files into and read files out of the 7651 memory. The files are input and output as binary block data.

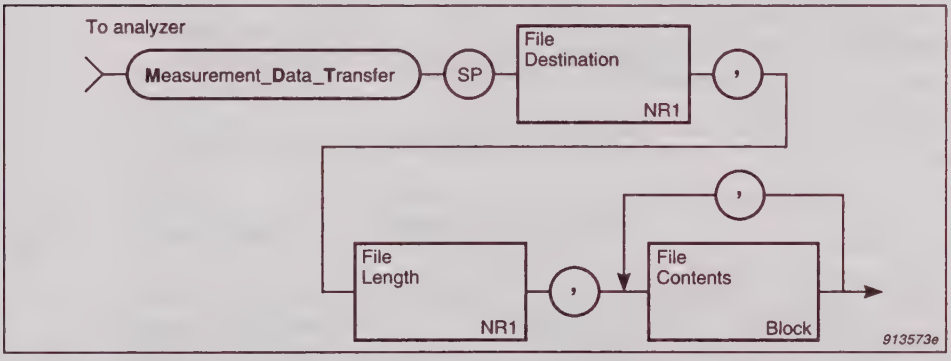

*Fig. 5.14(a) Syntax for the **M_D_T** command message*

Examples

Current Measurement
To obtain a readout of the current measurement, the controller sends:

```
M_D_T? C
```

The analyzer responds with (400 lines, autospectrum):

```
M_D_T #44224<data contents>
```

Numbered File
To obtain a readout of file number 1, the controller sends:

```
M_D_T? 1
```

The analyzer responds with (400 lines, cross mode):

```
M_D_T 1,4809,#44809<set-up contents>
<data contents>
```

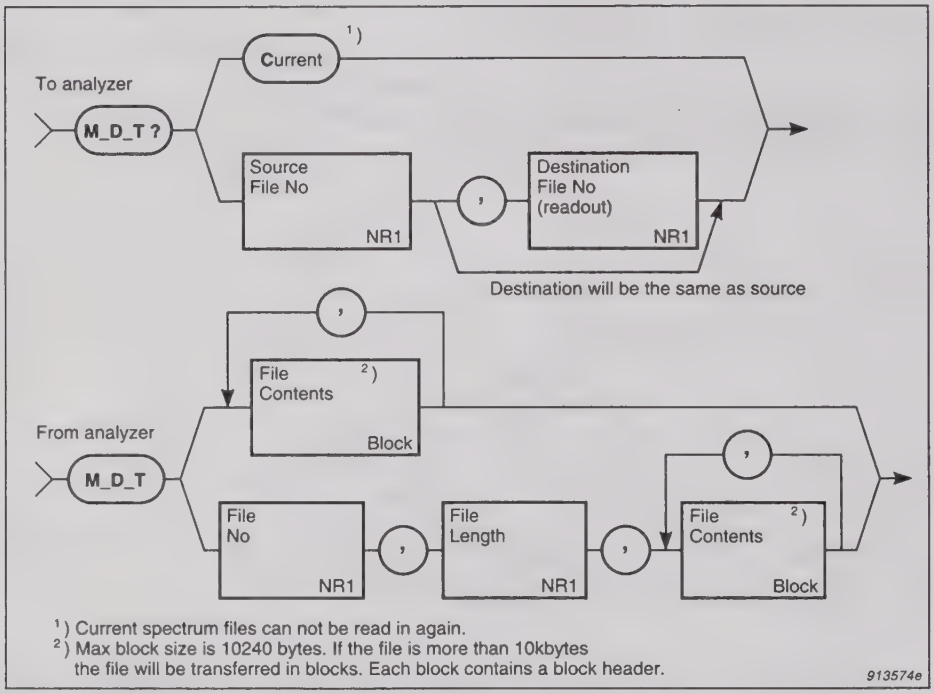

*Fig. 5.14(b) Syntax for the **M_D_T?** query message and analyzer response*

Change File Number
To readout of file number 1 as file number 100, the controller sends:

```
M_D_T? 1,100
```

The analyzer responds with (440 lines, cross mode):

```
M_D_T 100,4809,#44809<set-up contents>
<data contents>
```

For further details of the block data format, see Chapters 4 and 10 of the 2144 User Guide, Vol. 2.

Notes:

- If you attempt to read in and save a file using a file number which already exists (or an illegal file number), the file is not saved. The analyzer generates an error message, and sets the

ABnormal bit in the status byte. If you want to use an existing file number, then first rename or delete the existing file.

- If a non-existent file number is specified for output, the analyzer generates an error message, and the ABnormal bit in the status byte is set.
- The current measurement may be read out. It cannot be loaded back into the 7651, however, as it does not contain the disk memory format. With **Current** measurement, all available spectra are read out.
- With RS–232–C operation, 8 data bits must be used.

5.4.3 Data_Memory_Read? (D_M_R?)

New to Type 7651. The **D_M_R?** message (query only) returns a readout of a specified spectrum or time record from memory. This readout comprises a description followed by a number of Y-values (dB or absolute units).

The qualifier can be:

V = Valid
O = Overload
N = Negative
P = Positive

File Type
File Type is determined by the domain (frequency/time) and measurement type with which the file was saved.

When saved as 1-channel time record, File Type can be
A and **Auto_A** or
B and **Auto_B**

When saved as 2-channel time record, File Type can be
A, **B**, **Auto_A**, and **Auto_B**

When saved as 1-channel autospectrum, File Type can be
Auto_A or **Auto_B**

When saved as 2-channel autospectrum, File Type can be
Auto_A and **Auto_B**

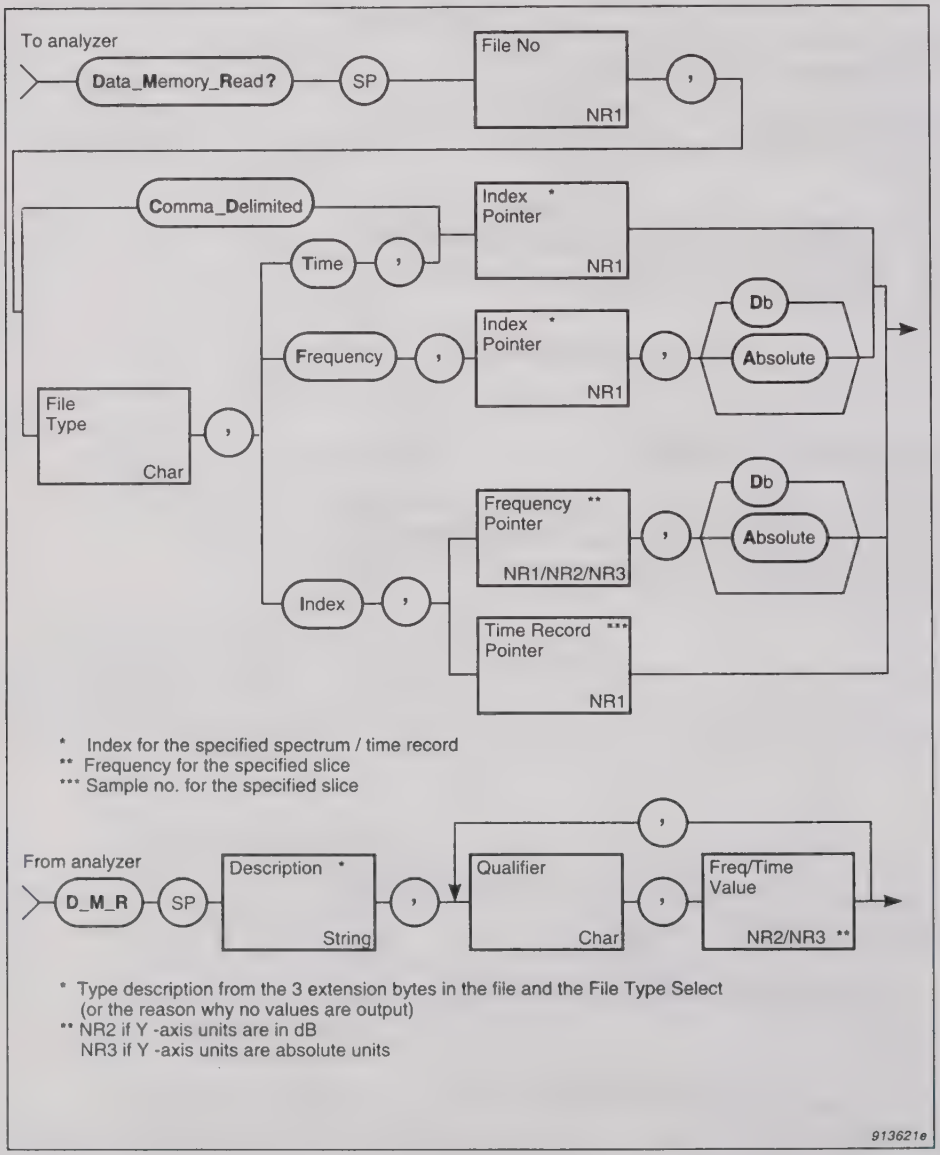

*Fig. 5.15 Syntax for the **D_M_R?** query message and analyzer response*

When saved as 2-channel cross-spectrum, File Type can be
`Auto_A`, `Auto_B`, `Cross_Real`,
and `Cross_Imaginary`

Example:
To obtain a readout from memory, the controller could send:

```
D_M_R? 1,A_A,F,1,DB
```

The analyzer responds with (for example):

```
D_M_R "SINGLE,CROSS SPECTRUM,
  400 LINES,AUTO-A",0.00,"V",
  12.34,2.50,"V",3.45,,...
```

5.4.4 Current_Measurement_Read? (C_M_R?)

New to Type 7651. The **C_M_R?** message (query only) returns a readout of results from the currently displayed spectrum or time record. The start line of the readout, the spectrum, and the number of values read out can be specified. The readout may be in dB or absolute units. The data fields and the associated codes are listed in Table 5.12.

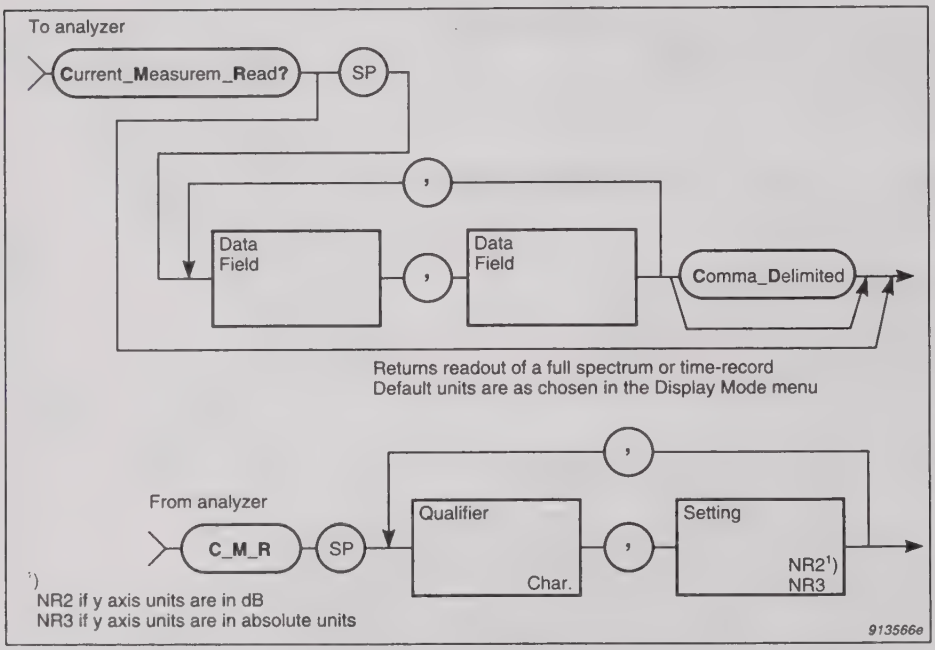

*Fig. 5.16 Syntax for the **C_M_R?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Start		NR3	Default is the first line (= 0)
Number	<numeric> Max	NR1 Char.	Default is one line ①
Y_Axis_Unit②	Db Absolute linear	Char.	
Measurement	Upper Lower	Char.	Defaults chosen in measurement-mode

T03515GB0

① Too great a value is interpreted as Max
② When Comma_Delimited has bee selected, the Y_Axis_Unit will be dB for spectra and Absolute for time records

*Table 5.12 **Current_Measurement_Read?** data fields and codes*

The qualifier can be:

V = Valid
O = Overload
N = Negative
P = Positive

Examples:

Full measurement readout

To obtain a readout of the current measurement in full, the controller sends:

```
C_M_R?
```

The analyzer responds with (for example):

```
C_M_R V,79.76,V,81.97,V,66.13,V,...
```

Partial measurement readout

To obtain a readout of a specified part of the current measurement, the controller might send:

```
C_M_R? Sta,100,N,3,Y_A_U,DB
```

The analyzer responds with (for example):

```
C_M_R V,32.45,V,45.67,V,58.73
```

Chapter 6

Specifications

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6.2 Additional Specifications 7651 6-2

6.1 Specifications 2144

See separate 2143/44 Product Data (BP 1021) or 2144 User Guide, Vol.1 (BB 0768), Chapter 11.

6.2 Additional Specifications 7651

Analogue Part

SYSTEM ACCURACY:
Dynamic Range: All distortion (intermodulation and harmonic) and spurious noise at least 80 dB below max. input voltage
Overall Frequency Response: ±0.1 dB from lower frequency limit (0.3 Hz) to upper frequency limit
Amplitude Linearity: ±0.05 dB or ±0.005% of max. input voltage, whichever is greater, measured using sine wave input
Frequency Accuracy and Stability: 0.01% without warm-up (no adjustment necessary)

NOISE (total noise excl. DC):
Voltage Input: < 1 μV with input range 10 mV (80 dB FSD) and input short circuited
Charge Input: < 10^{-2} pC with input range 5.6 pC and 1 nF transducer capacitance

CHANNEL–TO–CHANNEL MATCH:
Max. Gain Difference: 0.1 dB from lower frequency limit (0.3, 0.7 or 20 Hz) to upper frequency limit (12.8 or 25.6 kHz)
Max. Phase Difference:

50 to 315 Hz	< 0.017 deg.
315 to 630 Hz	< 0.021 deg.
630 Hz to 1.25 kHz	< 0.042 deg.
1.25 to 2.5 kHz	< 0.083 deg.
2.5 to 5 kHz	< 0.166 deg.
5 to 15 kHz	< 0.333 deg.

Fourier Transform

Resolution: 51, 101, 201, 401, or 801 spectral lines corresponding with time records of 128, 256, 512, 1024, or 2048 samples. In zero pad mode the time record is 64 to 1024 samples padded with zeros
Weighting: Rectangular, Hanning, Flat-top, Transient, Exponential. Transient and Exponential windows have selectable position and length
Calculation Rate: Calculation of 401-line autospectrum takes < 5 ms including weighting and averaging
Frequency Range: 0.7 Hz to 25.6 kHz in binary sequence. Baseband or Zoom. 15 frequency spans from 1.56 Hz to 25.6 kHz. Resolution of zoom centre frequency setting is 4 Hz for all frequency spans (8 Hz in 1-ch. mode)
Real-time Frequency Range: > 25.6 kHz in both single and dual channel mode, for 800 lines and 67% overlap (equivalent to 80kHz single/dual channel for 800 lines and 0% overlap)

Averaging

Exp.: 1 to 16384 averages. Binary sequence
Lin.: 1 to 32767 averages. Equal weight. Any integer
Overlap: 0%, 50%, 67%, 75%, or maximum
Overload Reject: Any block of data related to overload can be rejected from an average. The hysteresis time after detection of overload can be set in seconds.

Hold

Peak Hold: Measures and holds the max. level of the input signal in one channel
Max/Min Hold: Two different hold functions can be applied simultaneously

Multifunction Trigger

Mode Options: Single Measurement (time record or spectrum), Normal Multispectrum/ Time Capture, Gated Multispectrum, Matrix Multispectrum
Trigger Types: Internal, External, Clock, Manual, Free-run
Internal Trigger: On channel A or B after digital low-pass filtering. Trigger slope selectable
Measurement Start: One measurement trigger starts a measurement process
Record Trigger: One record trigger starts collection of one block of data

Delay, Trig → Ch. A: Single and Gated mode: T① to 9999 s. Resolution is ΔT② for zoom, 2ΔT for baseband (up to T for some set-ups). Normal mode: –16 ms (or up to several sec.) to 9999 s. Resolution is T/2
Delay, Ch. A → Ch. B: 0 to 999 s. Resolution is ΔT for zoom, 2ΔT for baseband
Trigger Accuracy: Internal and external in Single and Gated with Delay Trig. → Ch. A ≥ 0: resolution is ΔT for zoom, 2ΔT for baseband. All other modes: resolution is 1 ms

① T is the length of one block of data
② ΔT is the sampling time interval

Display

Measurement Types: 1-channel analysis, 2-channel analysis, auto & cross analysis
Functions Calculated and Displayed:
Time Domain: Time Record A & B, Complex Time, Autocorrelation A & B, Cross Correlation, Impulse Response h1
Frequency Domain: Inst. Spectrum A & B, Autospectrum A & B, Cross Spectrum, Mean Sound Pressure, Particle Velocity, Complex Intensity, Frequency Response H1, H2, H3, 1/H1, Coherence, Pressure–Velocity Coherence, Coherent and Noncoherent Output Power. Single or double differentiation and integration
A-weighting: Analogue A-weighting of input signal in both channels possible
Bow-tie Correction: Correlation function can be displayed with or without bow-tie correction

Y–AXIS:
Annotation: Absolute (metric or imperial) or relative units (dB). Selectable dB reference
Spectrum Scaling: RMS, PWR, PSD, or ESD
Coordinates: RE, IM, MAG, PHASE
Units: V, V^2, V^2/Hz, V^2s/Hz, W/m^2, Deg, or Unit related to units defined in the measurement set-up
Log. Range: 10, 20, 40, 80, or 160 dB
Phase Range: ±0.2°, ±1°, ±5°, ±45°, ±90°, ±180°, +0°/–360°

X–AXIS:
Spectrum Display: Linear scale with annotation in mHz, Hz or kHz. Upper range from 781.25 mHz to 25.6 kHz in full display
Time Display: Scale annotated in ms or s. Length from 6.1 ms to 1600 s

CURSORS:
Cursor Types: Main, Harmonic, Sideband, Delta, Reference. Individual or aligned control of cursors on upper and lower graphs
X-readings: Time, Frequency, or Line Number (#X). Harmonic or Sideband Number. Difference between main and reference cursor positions
Y-readings: Calibrated and scaled, absolute or relative units (as Y-axis). Total or A-weighted power or energy. Power or energy in Delta Cursor band or on harmonics. Delta band/Total. Level difference between Main and Reference, Harmonic or Sideband cursors

Memory

Memory Size: 512 kbytes. 128 992 bytes Data Memory corresponding to, for example, 15 801-lines cross spectra or 30 time records 2048 samples long
Max. Multispectrum Update Rate: 512 spectra/second (1 average between spectra).

Accessories Included

VP 7279.....System Software
VP 5278..... Software Key

Accessories Available

WH 2921.....Memory Extension (to 2 Mb)

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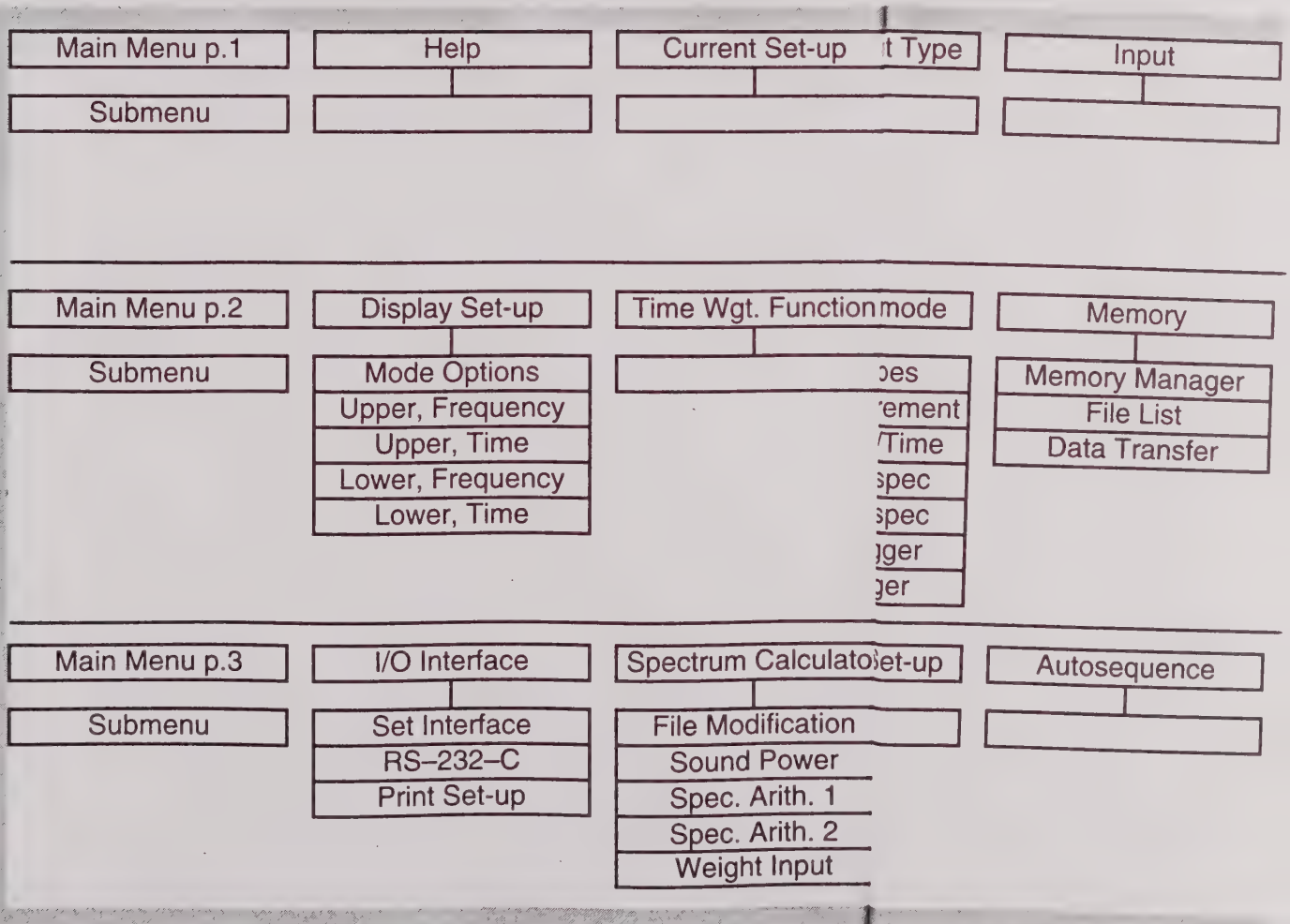
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7651

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Technical Documentation

ual Channel Real-time Frequency Analyzer
e 2144

ol. 1: Operation

User Guide · User Guide · User Guide ·

User Guide
Real-time Frequency Analyzer
Type 2144

From serial no. 1614490
using system software VP 7278

December 1991

Brüel & Kjær

BB 0768–11

Safety Considerations

This apparatus has been designed and tested according to IEC Publication 348, *Safety Requirements for Electronic Measuring Apparatus*, and has been supplied in safe condition. The present User Guide contains information and warnings which should be followed by the user to ensure safe operation and to retain the apparatus in safe condition. Special note should be made of the following:

Powering the Apparatus

Before each use of the Power Supply ZG 0199 with the apparatus, check that it is set to match the available mains voltage and that the correct fuse is installed.

Safety Symbols

⚠ The apparatus will be marked with this symbol when it is important that the user refers to the associated warning statements given in the User Guide.

Warnings

- Switch off all equipment before connecting or disconnecting their digital interface. Failure to do so could damage the equipment.
- Whenever it is likely that the correct function or operating safety of the apparatus has been impaired, the apparatus must be made inoperative and be secured against unintended operation.
- Any adjustment, maintenance and repair of the open apparatus under voltage must be avoided as far as possible and, if unavoidable, must be carried out only by trained service personnel.

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1.1 About Type 2144

Dual Channel Real-time Analyzer Type 2144 is a portable, digital-filter, frequency analyzer for acoustics, electroacoustics and vibration measurements. Its light weight and water-protected cabinet make it especially well suited for use in the field. Yet its measuring capabilities easily match those of a laboratory instrument. The 2144 features real-time single channel operation across the whole audio frequency range. For dual channel operation, the real-time frequency range is halved.

The 2144 is operated by means of user-interactive menus. This enables you to quickly become familiar with the use of the analyzer. Access to a system of on-screen help pages provides you with information about the use of the menus at any time and in any place.

A large internal non-volatile memory together with back-up disk storage facilities make Type 2144 a powerful data-gathering device. The IEEE 488 and RS–232–C interfaces allow data-processing and external control.

1.2 About This User Guide

This user guide introduces you to the operating principles of Type 2144 and gives you an overview of the analyzer's possibilities. Examples of measurement procedures and data processing are also given. You will find that the analyzer is very easy to use once you have become familiar with its working principles.

Summary of Contents

Chapter 2 contains information about electrical considerations and maintenance of the 2144. It is important that you read this *before* you start using the analyzer.

Chapter 3 describes the buttons on the front panel and the connections on the rear panel.

Chapters 4, 5, and 6 describe the set-up and calibration of the analyzer, how to make measurements, and how to save the data.

Chapters 7 to 10 describe some of the analyzer's special functions

with examples of use.

Chapter 11 contains the technical specifications and Chapter 12 is about service and repair.

Chapter 13, the appendix, describes different types of error messages and how to deal with them. The index is in Chapter 14.

Use of the interfaces (serial and parallel) is described in Vol. 2: Interface.

2.1 Power Supply

Type 2144 can be powered using internal batteries, an AC mains supply, or a car battery as an external DC supply.

2.1.1 Battery Installation

Suitable batteries for Type 2144 are 1.25 V rechargeable NiCd batteries, type R 20 ("D" size). These have Brüel & Kjær order numbers QB 0008. Six QB 0008 are supplied with Type 2144. Type 2144 will operate continuously for more than 4 hours (at 25°C) with a set of fully charged batteries. Alkaline batteries can be used for up to 6 hours. The operating time is reduced if the disk-drive is used or the temperature decreases.

Batteries are inserted into Type 2144 in the following way:

1. Remove the Battery Box ZG 0146 by turning the release screw.
2. Remove the cover by turning the four corner screws.
3. Insert six batteries in the directions indicated inside the box.
4. Replace cover and insert box into Type 2144.
5. Secure by turning the release screw.
6. Label battery box with type of batteries contained.

Caution! It is possible for batteries to explode or leak if they are handled incorrectly, so:

- Never attempt to recharge non-rechargeable batteries.
- Never attempt to recharge batteries fitted the wrong way round.
- Never mix different makes or types of battery.
- Never mix charged and discharged batteries.
- Always label the outside of the battery box with the type of batteries contained.
- Always remove the battery box before storage or shipment.

2.1.2 Mains Supply

To power Type 2144 from the mains supply, Power Supply ZG 0199 (included as accessory) can be connected to the **External Power** 7-pin DIN plug on the rear panel via Cable AQ 0035. This arrangement is shown in Fig. 2.1. Alternatively, ZG 0199 can be inserted in place of the battery box.

⚠ **WARNING:** NEVER apply an external drive voltage to the analyzer when there are non-rechargable batteries in it.

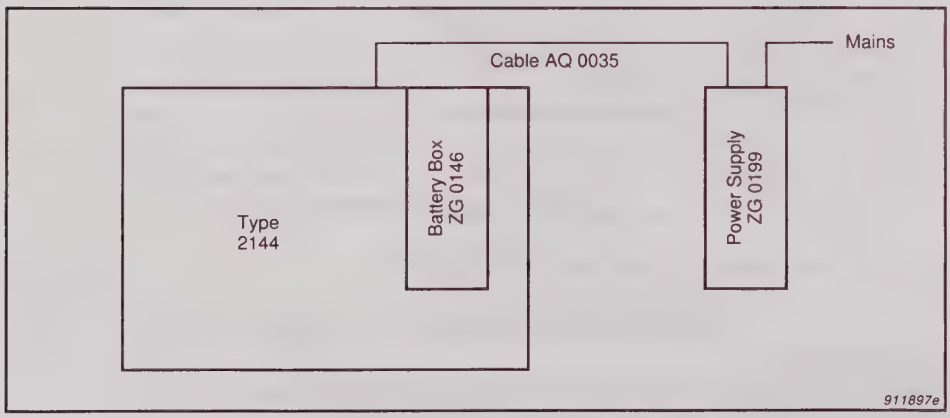

Fig. 2.1 Arrangement for powering or recharging

2.1.3 Recharging the Batteries

Power Supply ZG 0199 can be used to recharge the analyzer's NiCd batteries when the analyzer is switched off, for example overnight. The time taken to fully recharge the batteries is approximately 14 hours. The batteries can be recharged about 1000 times, provided they are not overcharged (i.e. not more than 16 hours). The arrangement for this is shown in Fig. 2.1.

Note: The switch on ZG 0199 must be in position **Drive Voltage On** for both powering and recharging. The charge LED does *not* come on.

Simultaneous Powering and Recharging

For simultaneous powering and recharging, use the arrangement shown in Fig. 2.2. The switch on ZG 0199 must be in position **Charge On, Drive Voltage On.**

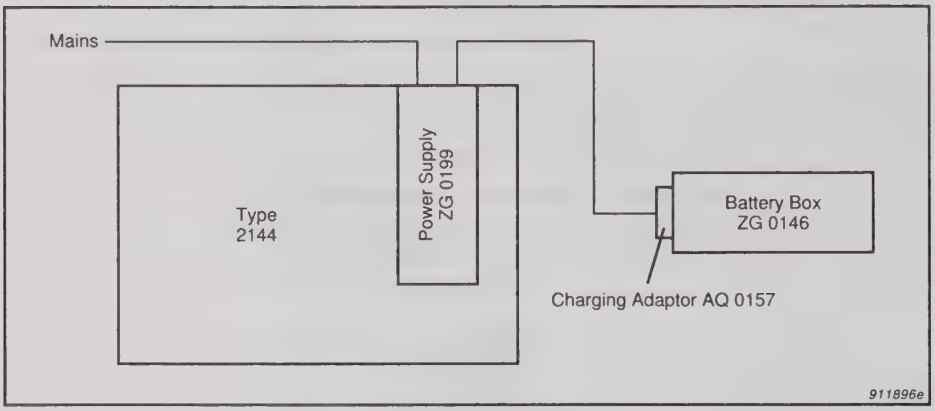

Fig. 2.2 Arrangement for simultaneous powering and recharging

Note on Rechargable Batteries

The cells cannot be overcharged, but their lifetime can be reduced if a charging current is applied for too long a period. Likewise, NiCd cells may exhibit a "memory effect" if used incorrectly. This effect leads to a decreased operating time but can be avoided by letting the analyzer run to cut-off every time before recharging the cells (it is a good idea to have an extra set of charged cells ready). Your measurements are saved when the analyzer cuts off.

If, however, the operating time becomes considerably less than 4 hours, the "memory effect" problem can usually be overcome by deep discharging the cells:

1. Discharge the cells, for example by using them to power a flashlight until they are completely run down.
2. Charge the cells for 20 to 24 hours.

2.1.4 Use of a Car Battery for External DC Supply

If a car battery is used as the external DC supply and this is installed in a car, power should be taken at a point after the car's fuseboard, or, when the car is equipped with an electric lighter socket, power can be taken from here. To facilitate connection, the cigarette lighter should be replaced by a suitable adaptor-plug which has a built-in fuse. The plug should be mounted on a cable with a 7-pin DIN plug at the other end. For pin connections, see section 3.2). When possible, it is best to leave the car ignition switched off to avoid interference problems while using the analyzer.

The power supply in Type 2144 is isolated from its chassis and therefore cannot short-circuit the car battery if the analyzer's chassis (or the housing of a microphone) touches the chassis or bodywork of the car. However, if other instruments are used with the analyzer, ensure that they are also properly isolated as otherwise they can short-circuit the car battery.

2.2 Grounding Considerations

Indiscriminate grounding of instruments in a measurement system can introduce ground-loop interference from magnetic fields. Ground loops are created where multiple ground paths exist between two or more points in the measurement system, for instance where two instruments are interconnected by two separate signal lines. Circulating currents in these ground loops generate noise voltages which can lead to less accurate measurements. In extreme cases, the interference generated can also disrupt the digital communications in a bus-based system. Type 2144 terminology operates with three different ground symbols: signal ground, analogue ground, and chassis ground (rear panel). When the grounding switch on the rear panel is in **"Chassis"** position, analogue ground is connected to the chassis (see Fig. 2.3). In **"Floating"** position, analogue ground is disconnected to help break possible ground loops.

WARNING! Care must be taken to limit the Signal Ground current in order to prevent electrical hazards. Maximum is 50 mA.

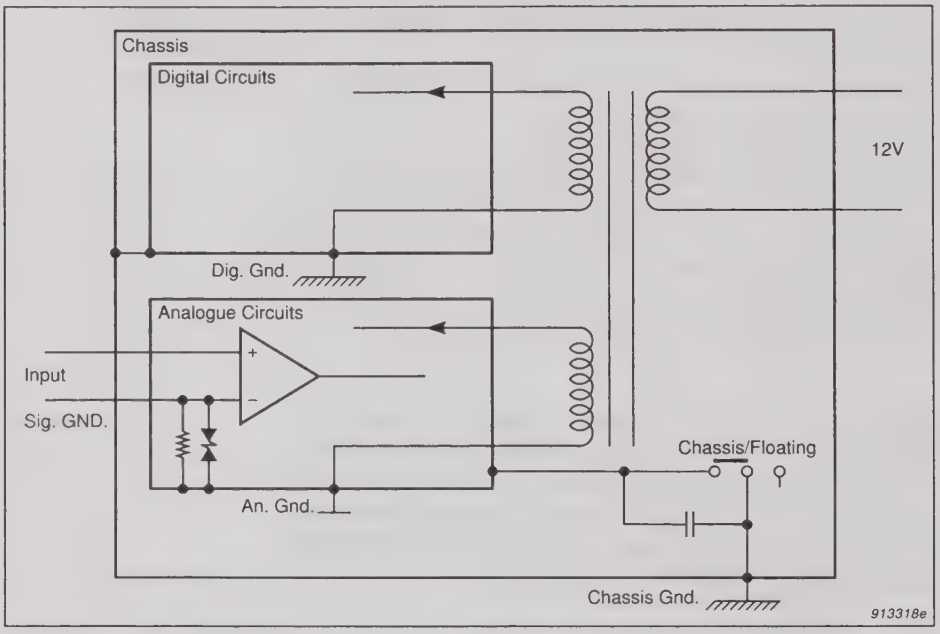

Fig. 2.3 Simplified circuit diagram showing the grounding principle of Type 2144 (one input channel shown)

If Type 2144 is part of a measurement system consisting of several instruments, use the following procedure to ensure that ground loops are eliminated without affecting the operating safety of the system.

1. Switch all instruments **"Off"** before making any changes to ground connections.
2. Connect together the Signal Ground lines of all the instruments in the system – this is done automatically through the screens of signal input/output connections. Make sure that the **Signal Ground** switch is **"On"** on any instruments equipped with such a switch.
3. If there is more than one signal cable connecting any two instruments together, break the signal ground connection in all but one of the interconnecting cables, either by switching **Signal Ground "Off"** or by disconnecting the signal ground lines in the

cables. If this is not possible, use short cables and bunch the cables together to keep the area enclosed by cable loops as small as possible.

4. On all instruments which have a ground connection in their mains supply connector, connect the Chassis to mains ground. Disconnect Signal Ground from the Chassis on all but one of these instruments.
5. In IEEE/IEC bus-based systems, disconnect Signal Ground from Chassis on all but one of the instruments connected to the bus. Leave Signal Ground connected to the Chassis on an instrument with a mains ground connection, if any are included in the bus system. The bus cables provide a continuous chassis ground connection between the instruments.
6. Ensure that metal instrument cabinets do not touch each other, particularly if the chassis are connected to Signal Ground. In rack-mounted systems, use isolating flanges to prevent ground loops being formed through the rack itself.
7. If transducers with metal housings are used, isolate the housings from grounded surfaces.

⚠ **WARNING:** Type 2144 is designed to be operated with its analogue ground and chassis ground at zero potential. Voltage between these two may be hazardous and must therefore be kept within the specified safety limits (see Specifications, Chapter 11).

2.3 Cleaning the Disk-drive

It is advisable to clean the heads of the analyzer's disk-drive at regular intervals – once a month is recommended – to avoid errors when reading to or from the disk. For cleaning, a 3.5-inch Head Cleaning Diskette Kit is available (Brüel & Kjær part QA 0168).

1. Prepare the cleaning disk according to the instructions included in the kit.
2. Insert the disk in the disk-drive.
3. Press **"F7"** (`Memory`) on page 2 of the Main menu.

3.1 Front Panel

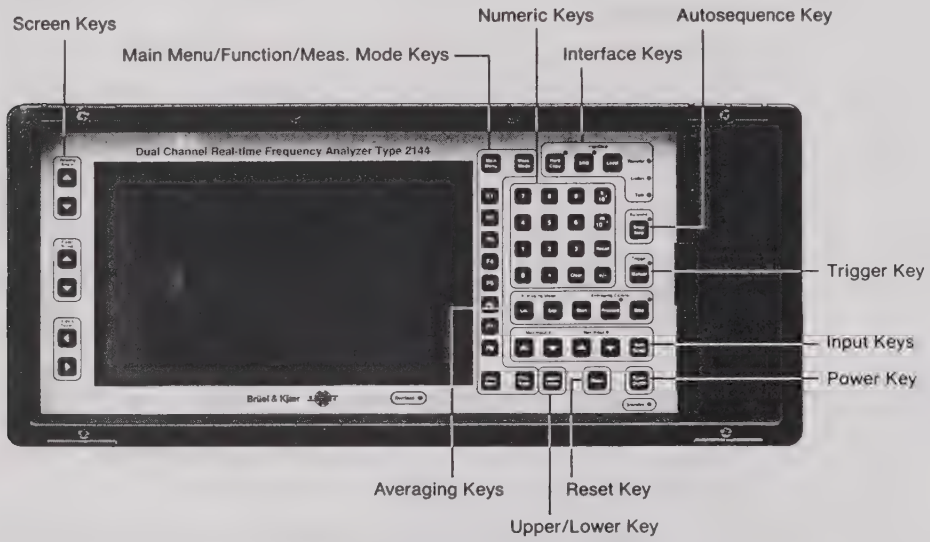

Fig. 3.1 Front Panel of Dual Channel Real-time Frequency Analyzer Type 2144

Screen Keys

Viewing Angle "▲/▼": The analyzer's display contrast can be adapted to different vertical viewing angles using these keys.

Y-axis Scroll "▲/▼": Step up and down the y-axis of the display selected with the **"Upper/Lower"** key.

X-axis Scroll "◀/▶": Step up and down the x-axis of the display. In dual and difference display modes both x-axes scroll.

Main Menu/Function/Meas. Mode Keys

"Main Menu": Displays page 1 of the Main menu, stopping any measurement in progress.

"Next Menu": Steps through the Main menu.

"Prev. Page": Steps backwards through the stack of previously used screen pages. The stack is 10 pages long.

"Meas. Mode": Puts the analyzer in measurement mode. To make a measurement, the analyzer must be in measurement mode.

"F1",...,"F8": These are soft function keys. Their functions depend on the menu in use and are described in the menu text. Where a ":" appears in the menu text, the setting can be obtained using the numeric keys.

Numeric Keys

These are used for entering numbers and prefixes into the echo field in the lower right corner of the screen display. On entering numerics, see section 4.4.2.

Interface Keys

"SRQ": Sends a Service Request to the controller.

"Local": Sets the analyzer in local operation mode.

"Hard Copy": Sends a copy of the screen display to a printer via the interface.

The function of these keys is described in detail in Vol. 2 of the User's Guide: Interface.

Averaging Keys

"Lin.": Sets the analyzer in linear averaging mode.

"Exp.": Sets the analyzer in exponential averaging mode.

"Start": Clears all four input buffers and starts a measurement if the analyzer is in Measurement Mode.

"Proceed": Continues an interrupted measurement without clearing the buffers.

"Stop": Stops any measurement in progress and freezes the display without clearing the buffers.

Autosequence Key

"Stop/Step": This key has three functions (see Chapter 8). It is used for terminating the programming of an autosequence, for stepping manually through the autosequence, and for executing it.

Trigger Key

"Manual": Triggers the analyzer if `Trigger Select` is set to `MANUAL` and `Trigger Mode` is set to `ACTIVE` in the Trigger Multimode menu (see section 5.3.3).

Input Keys

Max. Input A "▲/▼": These keys fix the upper limit of the A-channel's 80 dB dynamic range. The unit and reference depend on the input chosen.

Max. Input B "▲/▼": These keys fix the upper limit of the B-channel's 80 dB dynamic range. The unit and reference depend on the input chosen.

"Auto Range": Automatically sets the input attenuator of both channels to the optimal value according to the input levels. The input signal is measured over a period of time specified in the Averaging menu. If the level is too high, the signal is attenuated.

Upper/Lower Key

"Upper/Lower": Toggles between the upper and lower display if two spectra are displayed at a time. All operations affect the display pointed out with the Upper/Lower Indicator (see section 5.1).

Reset Key

"Reset": Resets the analyzer to the user-defined settings without losing any set-ups or data already stored in the analyzer.

Power Key

"Power On/Off": Switches the analyzer on or off.

Note: If the **"Power On/Off"** button is pressed while the disk-drive is active, the analyzer will wait until the disk-drive has stopped running before switching off.

3.2 Rear Panel

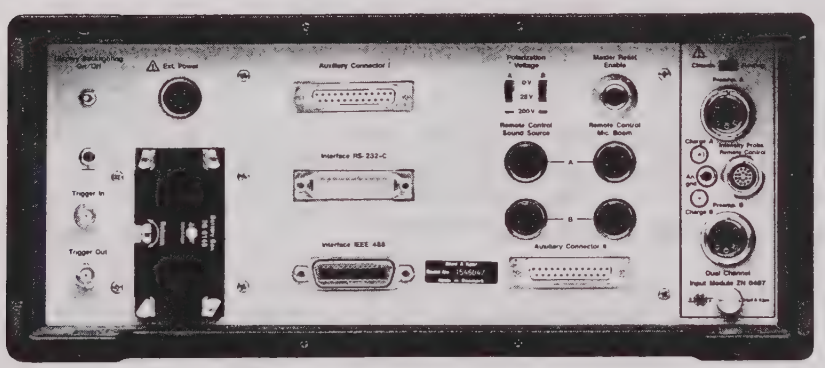

Fig. 3.2. Rear Panel of Dual Channel Real-time Frequency Analyzer Type 2144

Polarization Voltage A & B
Selects a microphone polarization voltage of 0, 28, or 200 V for each input as given on the microphone calibration chart.

Note: Always select the correct polarization voltage before switching the analyzer on. Otherwise, you may have to wait 10 to 15 minutes for the equipment to settle.

"Master Reset Enable"

This switch enables you to reset the analyzer to factory-defined settings. All saved data will be lost when a Master Reset is made. To master reset the analyzer:

1. Press **"Master Reset Enable"** and keep it pressed.
2. Press the **"Power On/Off"** key on the front panel.
3. Release the **"Power On/Off"** key.
4. Release **"Master Reset Enable"**.

Auxiliary Connector I

Reserved for future options.

Auxiliary Connector II

Reserved for future options.

Interface RS–232–C

For controlling the 2144 from a computer. Also used for connection of the analyzer to graphics printers (see separate interface manual).

Interface IEEE–488

24-way socket for digital output of measurement results and for remote control of the analyzer (see separate interface manual) via the IEEE–488 interface. Also used for printers with IBM, HP or Epson print formats or for Brüel & Kjær Graphics Recorder Type 2313.

WARNING! Switch off all equipment before connecting or disconnecting their digital interfaces, Failure to do so can damage the equipment.

Remote Control Sound Source 1 & 2

Two 8-pin DIN connectors for remote control of Sound Source Type 4224. Pin designations are given in Fig. 3.3.

Remote Control Mic. Boom A & B

Two 8-pin DIN connectors for remote control of Rotating Microphone Boom Type 3923 or Eight Channel Multiplexer Type 2811. Pin designations are given in Fig. 3.3.

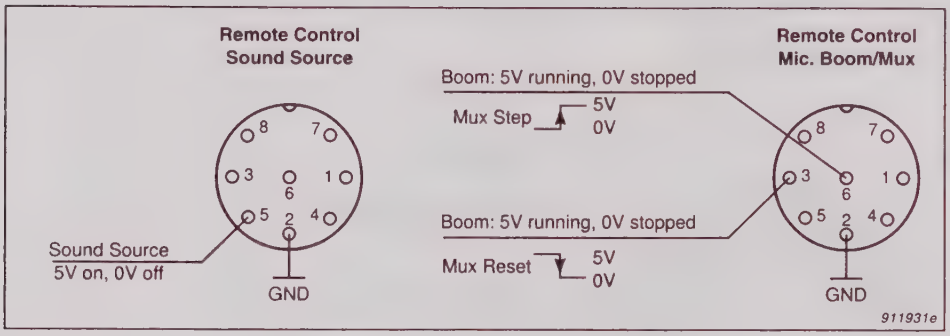

Fig. 3.3 Pin designations for Sound Source (left) and Microphone Boom/Multiplexer (right) connectors (outside view)

Preamplifier A & B

Two 7-pin connectors for Brüel & Kjær microphone preamplifiers. Pin designations are given in Fig. 3.4.

Preamplifier-to-BNC adaptors WJ 0185 (included as accessories) must be used for direct signals.

Charge A & B

Two 10–32 UNF micro connectors for connection of Brüel & Kjær accelerometers to the built-in charge sensitive amplifiers.

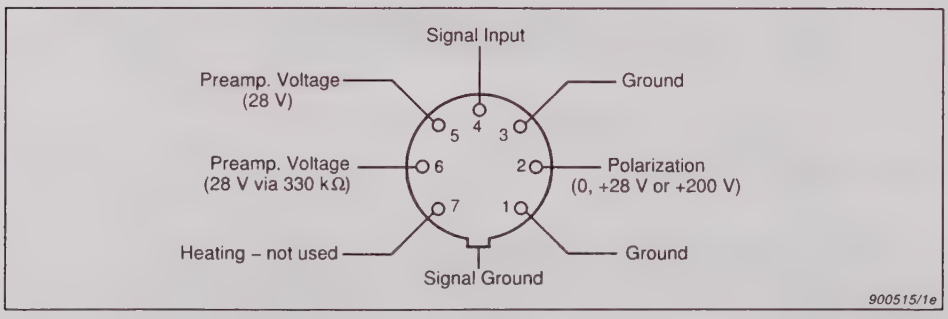

Fig. 3.4 Pin designation for 7-pin preamplifier connector (outside view)

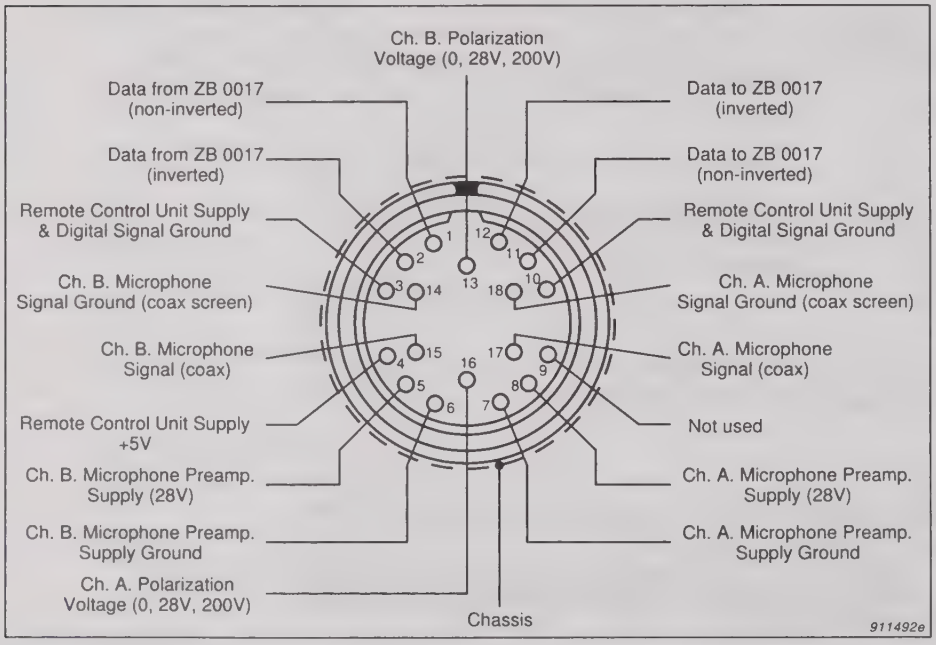

Fig. 3.5 Pin designation for 18-pin Intensity Probe / Remote Control connector (outside view)

Intensity Probe/Remote Control

18-pin LEMO socket for use with Brüel & Kjær Sound Intensity Probe Type 3548 including Remote Control Handle ZB 0017. Pin designations are given in Fig. 3.5.

Sound Intensity Probe Type 3545 may also be used with the 2144, but not all the remote control functions are available.

Trigger In/Out

For input of an external trigger signal as provided, for example, by Photoelectric Probes MM 0012 and MM 0024, or output of a trigger signal from the analyzer.
Note: There is a risk of damage to the Trigger Input if the trigger signal is outside the range 0 V to + 5 V.

0 V to 0.9 V is registered as *low* and 3.3 V to 5 V is registered as *high*. Triggering is on the *negative* slope of the trigger signal (see Fig. 3.6).

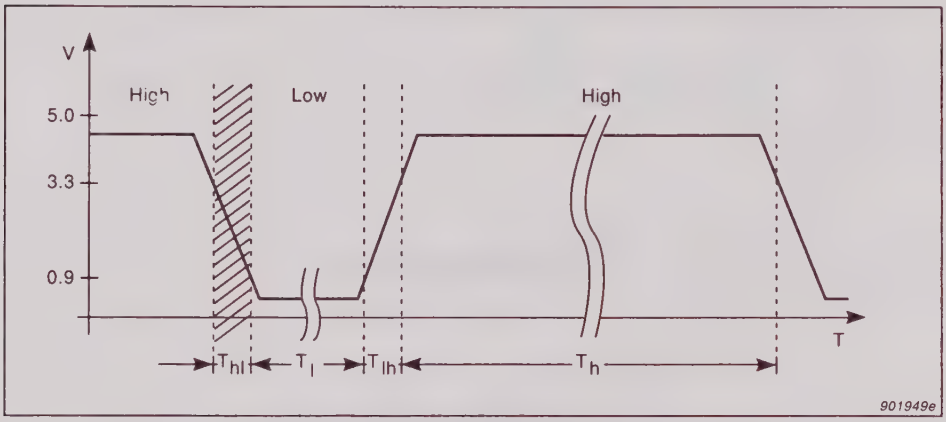

Fig. 3.6 Trigger signal used for external triggering. Triggering occurs in the cross-hatched area

The shift from high to low (T_{hl}, see Fig. 3.6) should be kept as short as possible (preferably less than 5 μs) and the duration of time that the trigger signal is kept high or low (T_h or T_l) must be greater than 100 ns to ensure that the signal stabilizes. The minimum time between two external triggers ($T_{hl} + T_l + T_{lh} + T_h$) is 2 ms for exponential averaging and the selected averaging time plus 1 ms for linear averaging. If the pulses are sent at a faster rate, they are ignored.

Display Backlighting On/Off

Toggle switch for activating or de-activating the analyzer's backlighting mode.

Ext. Power

7-pin DIN socket for connection of an external power supply such as Power Supply ZG 0199 with cable AQ 0035. Pin designations are shown in Fig. 3.7. The socket is also used when recharging NiCd batteries. Alternatively, the ZG 0199 can be plugged into the 2144 instead of the battery box ZG 0146. When using an external power source, the voltage must be in the range 11 V to 16 V DC (see section 2.1).

⚠ **WARNING:** NEVER apply an external drive voltage to the analyzer when there are alkaline or other non-rechargable batteries in it.

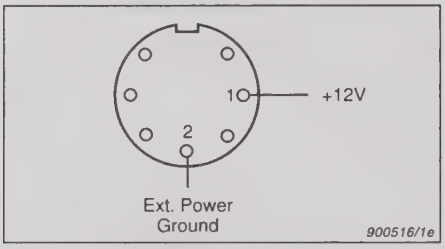

Fig. 3.7 Pin designation for 7-pin DIN external power connector (outside view)

Chassis/Floating

⚠ **WARNING:** Connects/disconnects analogue ground to/from the chassis (rear panel) of the 2144. See section 2.2 for further information on grounding considerations.

Chapter 4

Getting Started

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4.1 Switching On

Important: Ensure that you have read Chapter 2 (Installation and Maintenance) before you switch on the analyzer.

4.1.1 Normal Procedure

1. Press the **"Power On/Off"** key to switch the analyzer on.

When the analyzer is switched on, it goes through a three-step self test:

- The power-on self test looks for hardware failures.
- The program retention test checks if the different program parts are still in the analyzer's memory.
- The main program looks for errors in the internal memory (data memory, set-ups, autosequences, etc.).

Page 1 of the Main menu appears on screen when the self tests have been successfully completed. This takes about 35 seconds.

In case of error messages, see the appendix, Chapter 13. This describes different types of errors and how to deal with them.

4.1.2 Loading the Main Program

1. Select a program disk with either English, French or German help pages.
2. Insert the program disk in the disk-drive.
3. Make a Master Reset (see section 3.2).

The procedure described above

- switches the analyzer on
- loads the main program and the help pages into the analyzer
- resets the analyzer to its default (factory-defined) settings

4.2 General Measurement Procedure

With a transducer connected (remember to set the polarization voltage if you use a microphone), making a measurement with the 2144 is extremely simple:

1. Switch the analyzer on and wait for the self test to be completed.
2. Press the **"Meas. Mode"** key.
3. Press **Averaging Control "Start"** to start the measurement.

The measurement that you have just started is made with all parameters set as they were when the analyzer was last switched off. The way to change these settings is described in the following sections.

4.3 The Menu and Help Page System

The operation of the 2144 is based on a menu system. When the power-on self test is completed, the first page of the Main menu is shown on the display. You can always get to this page by pressing **"Main Menu"**.

4.3.1 Set-up Mode/Measurement Mode

When using the 2144, it is important to remember that it has two operating modes, Set-up (or Main Menu) Mode and Measurement Mode, selected by pressing **"Main Menu"** and **"Meas. Mode"**, respectively. When the analyzer is in its Set-up Mode, it is not possible to make measurements. When the analyzer is in its Measurement Mode, only the most important parameters of the set-up are accessible.

4.3.2 Getting Help

The first menu is called "Help". Each page of a menu has a help page associated with it. From any menu page (including Measurement Mode), you can go directly to the associated help page by

pressing **"Main Menu"** and then **"F1"**. Pressing **"Prev. Page"** takes you back to the menu you came from.

4.3.3 Overview of Menus

To give you an idea of the possibilities of the 2144, let us first look briefly at the different menus and their use.

Current Set-up
Gives you an overview of the settings currently in use.

Measurement Type
A very important menu. You can choose between four different "analyzers": one-and two-channel analysis, sound intensity analysis, and cross spectrum analysis. For each Measurement Type the analyzer has a complete set-up which is saved internally. The four Measurement Types are described in section 5.2.

Input
Input channel and signal conditioning are selected and the analogue input filters are set in this menu.

Calibration
The A- and B-channel signal levels can be calibrated either one at a time or simultaneously. dB references and units can be entered from the front panel. For intensity measurements, the intensity and particle velocity levels can be verified and the pressure–residual intensity index can be measured (see section 4.5).

Filter Bandwidth
Analysis can be made in $^1/_1$-, $^1/_3$-, $^1/_{12}$- or $^1/_{24}$-octaves, either in real-time or in several passes (see section 5.2).

Averaging
Linear averaging times from 1 ms to 24 h or exponential averaging times from $^1/_{512}$ to 512 s can be selected.

Display Modes
One or two spectra can be displayed at a time. Also, the axes of the graphs and spectrum unit must be defined. The choice of Spectrum Type is made in Measurement Mode.

Measurement Text

In addition to the number used to identify a file in the memory, a name or a comment can be assigned to it. This is a useful feature in the field where paper and pencil are not always available.

Hold

It is possible to hold the display or the individual frequency bands when they exceed or fall below their previous level. The hold functions specified in this menu can be activated in Measurement Mode.

Trigger Multimode

You can measure a single spectrum, a normal multispectrum, a gated multispectrum, or a matrix multispectrum. The related trigger conditions are set in this menu (see section 5.2).

Spectrum Weighting

Standard A-, B-, C-, and D-weightings and also user-defined weightings can be applied to the spectra during or after measurements (see section 9.2).

Data View

The data view facility is mainly intended for displaying multispectra. You can view a multispectrum along either the frequency axis or the time axis (slice). All information about the analyzer's setting when the spectrum was measured is available.

Memory

You can get a list of files in the data memory or on the disk, format new disks, delete or rename files, and transfer files between data memory and disk (see Chapter 6).

Spectrum Calculator

Spectra can be added or subtracted and constants can be added to or subtracted from spectra. Multispectra can be modified by substitution of one or more spectra. Spectrum Calculator also calculates sound power. The Spectrum Calculator is described in section 9.1.

I/O Interface

The analyzer communicates with the outside world through its interfaces. Either serial (RS–232–C) or parallel (IEEE 488) interface can be selected. See separate interface manual for more information.

Preselected Set-up
If you have any special settings that you want to use frequently, these can be saved in the analyzer's non-volatile memory. This facility is described in Chapter 7.

Autosequence
The analyzer can be programmed to make measurements without interference from an operator. Furthermore, it can be told to wake up at a particular time, make one or more measurements and then turn off again. See Chapter 8.

Real-time Clock
You can set the analyzer's internal watch. This is used for the wake-up facility and for time labelling the files.

Back Lighting
The LCD screen can be lit to make it visible in the dark. To save the batteries, the back lighting can be set to turn off automatically when the analyzer is not being operated.

Applications
The Applications menu differs from the other menus; in itself it is a one-page menu but it gives access to installed application programs. Selecting an application from this menu affects the access to some of the other menus, in effect giving you another analyzer. The 2144 comes with an application program for controlling microphone booms, sound sources, and multiplexers for building acoustics. This application is called "Boom and Mux" (see Chapter 10).

4.3.4 Efficient Use of the Menus

Two other useful keys in Set-up Mode are **"Next Menu"** and **"Prev. Page"**. **"Next Menu"** is useful for stepping through the menus without having to return to the Main menu. It is particularly useful during the initial set-up of the 2144 where the menus follow each other in logical sequence starting with Input.

"Prev. Page" allows you to "backspace" up to ten pages from the current menu page. For instance, if you wish to go back to the last-

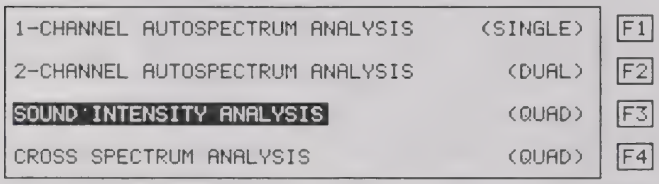
but-one displayed menu page to change a parameter, it is often quicker to press **"Prev. Page"** twice rather than access it through the Main menu, particularly if that page belongs to a different menu. **"Prev. Page"** is also useful together with **"Meas. Mode"** for rapid switching back and forth between a menu page and Measurement Mode when setting up interactive parameters such as screen displays.

4.4 Changing Parameters in the Set-up

4.4.1 Changing Operating Parameters in a Menu

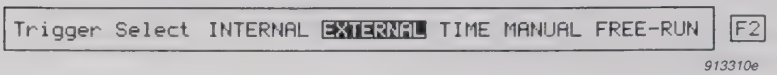
When the screen shows a menu selected from the Main menu, soft keys **"F1"**/.../**"F8"** are used to change operating parameters and, where the menu consists of more than one page, to move between the various menu pages. Operating parameters can be changed as follows:

- Where a soft function key controls a single parameter, pressing that key will select that parameter:


1-CHANNEL AUTOSPECTRUM ANALYSIS (SINGLE) F1
2-CHANNEL AUTOSPECTRUM ANALYSIS (DUAL) F2
SOUND INTENSITY ANALYSIS (QUAD) F3
CROSS SPECTRUM ANALYSIS (QUAD) F4

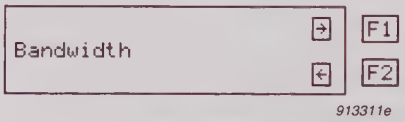
913309e

- Where a soft function key presents multiple choices, pressing that key will loop through the choices, an inverse video field indicating the selected choice:



913310e

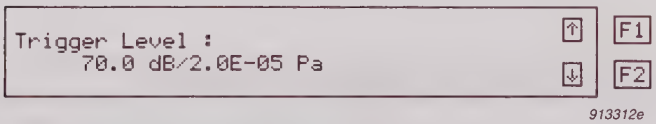
- Some multiple-choice parameters are selected using more than one soft function key, allowing movement of the inverse video field indicating the selected choice to the left or right and/or up or down:



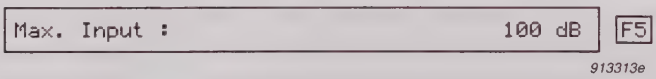
4.4.2 Changing Numerical Parameters in a Menu

Where a ":" appears in a function field, it indicates that the function field controls a numerical parameter. The values of numerical parameters can be changed as follows:

- Some numerical parameters can be incremented/decremented using increment/decrement soft keys:



- All numerical parameters can be changed using direct numeric entry. For direct numeric entry, the numeric keys on the front panel are used to key the required value into the echo field in the lower right-hand corner of the screen, and then entered by pressing the soft key adjacent to the function field. If the entered parameter value is invalid, the echo field flashes and the numerical parameter is set to the nearest valid value:



- Entry of a suffix is done using the **"k/10^3"** and **"m/10^{-3}"** keys. These keys have repeat functions. For instance, to key in a value in pico-units, the suffix is entered by pressing **"m/10^{-3}"** four times.

If the 2144 indicates an invalid parameter value despite this being within its specified allowed range, it will be because the entered value is inconsistent with the setting of another parameter elsewhere in the set-up. In this case, the rest of the set-up must be checked.

4.5 Calibration

To calibrate the analyzer, a reference source must be used to apply a known signal level to its inputs. A reference source for sound pressure calibration could be Pistonphone Type 4228, Sound Level Calibrator Type 4230, or Sound Intensity Calibrator Type 3541. For vibration calibration, the source could be Calibration Exciter Type 4294.

The following sections show an example of how to calibrate the analyzer for a sound intensity measurement. A ½″ two-microphone sound intensity probe (for example Type 3548) and Sound Intensity Calibrator Type 3541 are used in the example. The comments here also apply to calibration using accelerometers, hydrophones, or other transducers.

4.5.1 Calibration of the Sensitivity to Sound Pressure

1. Go to the Measurement Type menu (press **"Main Menu"**, **"F3"**) and select Sound Intensity Analysis.
2. Go to the Input menu (press **"Next Menu"**) and set `Input` to `PROBE/PREAMP`.
3. Press **"F8"** to go to the Calibration menu.

Page 1 of the Calibration menu (see Fig. 4.1) is used for setting up the physical parameters valid at the calibration. A summary of these parameters is given on the left-hand side of the screen. It is possible to change the dB reference but this should only be done when standards require it. Hydrophones, for example, use 1 μPa as reference.

4. Use soft keys **"F3"** to **"F5"** to enter values for microphone spacer, ambient pressure, and temperature. Also, enter the nominal density of the calibration media if you are not calibrating in air.
5. Press **"F7"** to go to page 2.
6. For simultaneous sound pressure calibration of both channels, arrange the microphones as described in the 3541 manual and set `Mode` to `A&B`.

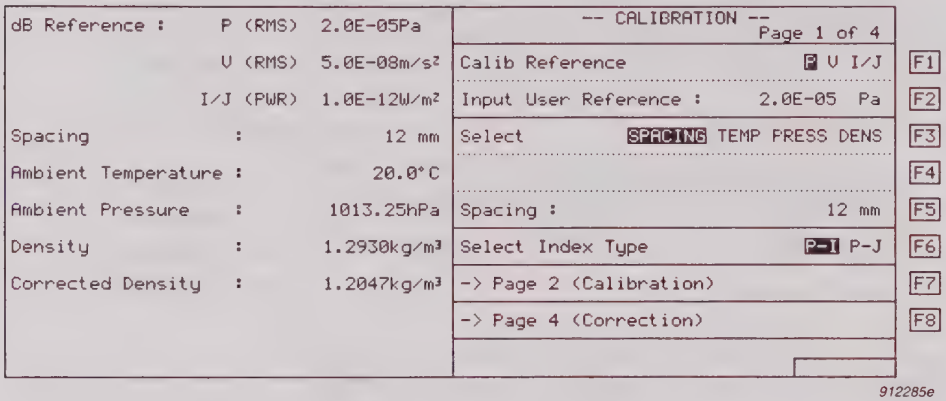


Fig. 4.1 Page 1 of the Calibration menu

7. Enter the values for calibration level, calibration frequency and microphone sensitivity. If you do not know the sensitivity of the probe microphones, use 12.5 mV.
8. Key-in a linear averaging time and enter it by pressing **"F6"**.
9. Press **"F7"** to start the autocalibration.

When the calibration is completed, the indicator returns to `FINISHED` and a gain factor for each channel is displayed in the `Gain Adjustment` field. This adjustment is added to all future measurements until the analyzer is re-calibrated or "Master Reset".

If no reference source is available and the sensitivity of the transducer is known from its calibration chart, an approximate calibration is possible by entering the sensitivity directly into the Calibration menu (**"F4"** on page 2).

4.5.2 Verification of the Sensitivity to Sound Intensity/Particle Velocity

To verify correct operation of the integrating circuit, the analyzer's sensitivity to sound intensity or particle velocity must be checked. This requires the use of Sound Intensity Calibrator Type 3541:

1. Place the microphones as described in the 3541 manual.

2. Go to page 3 of the Calibration menu. This page is only active if Sound Intensity Analysis has been chosen in the Measurement Type menu.
3. Set the Mode field to I or V.
4. Use **"F2"** to enter the intensity or particle velocity level (at reference conditions) as stated on the 3541's calibration chart.
5. Key-in a linear averaging time and enter it by pressing **"F4"**.
6. Press **"F5"** to make the verification.

No gain factors are added after the calibration. If, however, there is a large discrepancy between the measured and the entered calibration levels, check the instrument settings again and correct the faults.

4.5.3 Measurement of Residual Intensity

For sound intensity measurements it is not enough to ensure that the sound pressure and intensity/particle velocity levels are correct; the phase matching of the channels is equally important. To measure this, Sound Source ZI 0055 (included in Type 3541) is used and the microphones are placed opposite each other in the coupler. With this arrangement, the two microphones pick up a signal with the same amplitude and phase. In theory, the amplitude of the intensity signal should therefore be zero over the whole frequency range. To measure the residual intensity:

1. Select whether you want to display P - I (active) or P - J (reactive) index. This is done on page 1 of the Calibration menu (**"F6"**).
2. Go to page 4 of the Calibration menu (this page is only active in Sound Intensity Analysis mode).
3. Use **"F3"** and **"F4"** to set the high and low end of the frequency range as required for the intensity measurement you want to make later on.
4. Select a linear averaging time of, for example, 60 s (use **"F5"**).
5. Press **Averaging Control "Start"** to start the measurement.

When averaging stops, the correction spectrum is saved in the an-

alyzer's memory and the previous one (if any) is overwritten. Therefore, a file number can be given to the correction spectrum (by using **"F6"**), so that it is saved and can be recalled (**"F7"**) to the screen later on. A measurement text is automatically assigned to the correction spectra by the analyzer so that they can be identified in a file list. The measurement text reads "CORRECTION SPECTRUM".

When `Correction` is set to `ON` (by pressing **"F8"**), the measured intensity spectrum is corrected using the correction spectrum shown on page 4 of the Calibration menu. The correction formula is shown in equation 4.1:

$$I_{cor} = I_m - \frac{{p_m}^2}{{p_0}^2} I_0 \qquad (4.1)$$

where

I_{cor} = Corrected active intensity
I_m = Intensity in measurement
I_0 = Residual intensity in coupler
p_m = Mean pressure in measurement (RMS value)
p_0 = Mean pressure in coupler (RMS value)

Note: Equation 4.1* is only valid for small phase deviations. Also, a positive effect of this phase compensation is not guaranteed for all types of signals so it should be used very carefully. Changing the filter bandwidth automatically disables the correction algorithm.

If a corrected intensity spectrum is used for documentation, the pressure–residual intensity index spectrum must also be stated according to the ISO 9614–1 standard. The pressure–residual intensity index, δ_{pI_0}, is defined as:

$$\delta_{pI_0} = L_{p,0} - L_{I,0} \text{ dB} \qquad (4.2)$$

where

* Equation 4.1 is shown for active intensity. Reactive intensity is corrected in the same way.

$L_{p,0}$ = SPL in coupler
$L_{I,0}$ = Intensity level in coupler

The pressure–residual intensity index spectrum is unique to the measurement system with which it was measured. This means that if, for example, the microphone spacing of the probe is changed, then a new spectrum must be measured.

Chapter 5

Measurement Mode

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Gated Real-time Analysis 5–18
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Matrix Multispectrum Analysis 5–21

5.4 Sound Intensity Probe Type 3548 5–22

5.1 Screen Layout

5.1.1 Display

"Measurement Mode" designates the state where the analyzer is able to make measurements. In Measurement Mode, the analyzer screen is divided into two main parts: The display and the menu text. This section only describes the display; the menu text pages are described section 5.1.2. The display includes one or two sets of the following:

- Spectrum with axes and cursor
- Upper/Lower Indicator (not in single display)
- Display Header
- Status Fields

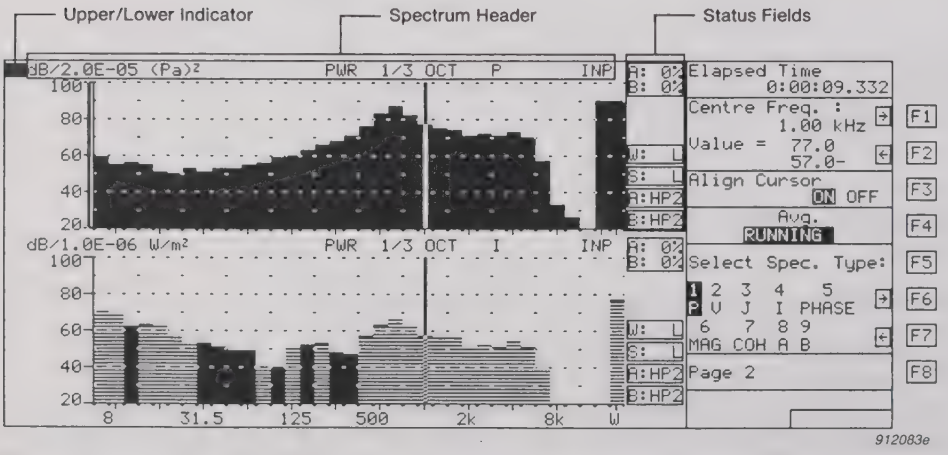

Fig. 5.1 A typical 2144 dual display in Measurement Mode. The intensity spectrum is shown in unipolar form

The following paragraphs all refer to Fig. 5.1.

Spectrum, Axes, Cursor
Changes to the display layout, such as single, dual or difference dis-

play, are made using the Display Modes menu. Changing the range of the axes can be done in Measurement Mode using the **"X-axis Scroll"** and **"Y-axis Scroll"** hard keys. The 2144 always shows the position of its dynamic range in relation to its Y-axis display range, indicated by a thicker bar parallel to the Y-axis, as an aid to setting the Y-axis correctly.

The 2144 always analyzes across its full frequency range (for example, 0.4 Hz to 10 kHz in dual channel 1/3-octave analysis). The *displayed* frequency range, however, can be controlled from the Display Modes menu. In this menu, it is also possible to decide whether to display cross spectra or intensity spectra in unipolar or bipolar form. In unipolar form, positive channels are solid and negative channels are striped.

Immediately to the right of a displayed spectrum, two further bands are displayed, namely the A/L- and W-bands:

A/L — The A/L-band is the measured broadband level according to the input filtering selected in the Input menu. If an input A-weighting is selected, the measured spectrum is A-weighted and this band gives the measured A-weighted level and is labelled A accordingly. Otherwise, the measured spectrum is linearly weighted and is labelled L. The upper and lower frequency limits are limited by the 25.6 kHz antialiasing filter and the selected input high-pass filter, respectively.

W — The W-band is the broadband level calculated from the measured input spectrum according to the weighting selected in the Spectrum Weighting menu (see section 9.2) and the input filtering selected in the Type of Input menu. This can be set independently of the A/L-band, but note that if analogue A-weighting is selected in the Type of Input menu, the weighting selected in Spectrum Weighting (for the spectrum or for the W-band) operates on A-weighted values.

The A/L-band is only shown in autospectra and in the p-spectrum in sound intensity analysis.

Upper/Lower Indicator

The black field on the far left of the display indicates which spectrum you are working with. In dual or difference display mode, this field toggles between the upper and lower spectrum when the **"Upper/Lower"** hard key on the front panel is pressed.

Display Header

The line of text over the display briefly describes the displayed data. This line consists of 6 fields:

1. The Y-axis unit shown in absolute units or as a dB/reference value and unit. `Unit` (upper case "U") is used as unit for direct input, `unit` (lower case "u") is used where Spectrum Unit is not RMS and integration or differentiation is chosen. In cases where the unit is not well defined, for example, if RMS is chosen for an intensity measurement, the unit field shows `****`. The dB reference is chosen in the Calibration menu.
2. Integration or differentiation. If neither has been chosen, this field is empty.
3. Spectrum unit (see section 9.3).
4. Filter bandwidth.
5. Spectrum type. This is chosen using soft keys **"F6"** and **"F7"**. In "difference" mode, the field displays the selected spectrum type minus the lower spectrum type, for example `A-B`.
6. This field indicates whether the displayed data is an input (`INP`), calculated (`CAL`), or recalled (`REC`) spectrum.

Status Fields

Down the right-hand side of the display are a series of boxes (status fields). These give from top to bottom:

1. Cumulative overload times for both input channels, shown as percentages of the averaging time (see section 5.1.3).
2. Correction (`CORR.`) for residual intensity. This can be activated in the Calibration menu (see section 4.5.3). The field is empty if Correction is not activated.
3. Trigger Mode. The trigger (`TRIG.`) can be activated in the Trigger Multimode menu. This field can also read `BM.` indicat-

ing that the Boom and Mux Application is active. Use of the Boom and Mux Application is described in Chapter 10. If Trigger and Boom and Mux are inactive, the status field is empty.

4. The name of the weighting function added to the W-band (`W:`) according to the setting of the Spectrum Weighting menu.
5. The name of the weighting function added to the displayed spectrum (`S:`) according to the Spectrum Weighting menu.
6. The setting of the analogue filter for the A-channel (`A:`) according to the Input menu.
7. The setting of the analogue filter for the B-channel (`B:`) according to the Input menu.

Getting Help in Measurement Mode

Help pages are also available in Measurement Mode. Each analysis mode (see section 5.3) has its corresponding help pages. They are obtained in exactly the same way as in Set-up Mode, that is by pressing **"Main Menu"** and then **"F1"** (`Help`). Pressing **"Main Menu"** stops any measurement in progress.

5.1.2 Menu Text

The text to the right of the display is the menu text. This consists of two pages. The pages can be alternated by pressing **"F8"**.

Page 1

Page 1 is common for all six analysis modes and gives:

1. An elapsed time counter giving the elapsed time in seconds since the measurement was started.
2. The cursor read-outs. The cursor(s) can be moved either by direct numeric entry or by using softkeys **"F1"** and **"F2"**.
3. Cursor alignment. When `OFF`, **"F1"** and **"F2"** control the cursor in the display pointed out with the Upper/Lower Indicator. When alignment is `ON`, the other cursor follows the one in the display pointed out with the Upper/Lower Indicator.
4. Averaging Status (left to right):
   (a) `HOLD` indicates that one or both spectrum hold functions

(max./min.) defined in the Hold menu are active (see section 5.3.1).

(b) The middle field can read READY (ready to start a measurement), RUNNING (a measurement is in progress), PAUSED (a measurement has been paused before completion by pressing the **Averaging Control "Stop"** key), FINISHED (a measurement has been completed), SETTLING (the digital filters are settling) or WAITING (waiting for a trigger, see section 5.3.3).

(c) The field to the right shows the pass number when the analysis is made in passes (see section 5.3.2).

5. Spectrum Type shown in the display pointed out with the Upper/Lower Indicator. The Spectrum Type can be changed by using **"F6"**, **"F7"** and/or numeric input.

Page 2

Page 2 changes with the analysis mode. Some of the fields, however, are common for all six modes and are described here:

1. Elapsed time counter (same as on page 1).
2. Averaging time and mode. The averaging time can be changed by using soft keys **"F1"** and **"F2"** or by direct numeric entry. This field also gives the averaging status (same as on page 1).
3. Whether or not the Display HOLD is being used. The measurement continues while the hold function is active but the display is not updated. This hold function works independently of the function(s) defined in the Hold menu. **"F5"** is used to select or deselect the display hold function.
4. The recall memory file. Soft key **"F8"** is used to recall the data from the displayed file number. The field automatically displays the next memory file when **"F8"** is pressed. Selection of a specific memory file is possible using direct numerical entry (see section 4.4.2). Note that the display automatically goes into Hold Mode when data is recalled to a single display or to both upper and lower display. To return to the display of current measurement data, **"F5"** must be pressed.

The rest of the fields are described in the sections dealing with their particular analysis mode (sections 5.3.1 to 5.3.6).

5.1.3 Overload Indication

Instantaneous Overload

Instantaneous overloads for both input channels are indicated by the **Overload** LED on the front panel.

Cumulative Overload

Cumulative overloads for each input channel are shown on screen in the overload `A:` and `B:` status fields in Measurement Mode. Each overload is calculated as the percentage of the averaging time.

Common Mode Overload

Common Mode overloads are indicated by the message `COMMON OVL.` in the error field in the lower right hand corner of the screen (just above the echo field). This type of overload occurs when the common mode input signal exceeds 2V (referred to analogue ground) and is likely to be caused by bad earth connections.

Analogue Protection

Severe overloads, such as electrical shocks, are indicated by the message `PROTECT` in the display error field. The analyzer short-circuits the inputs to analogue ground to protect the input filters and amplifiers. To escape from protect mode you can either press **"Reset"** or go to the Input menu and press **"F6"** (`Input Protect`).

5.2 The Four Measurement Types

The 2144 has four Measurement Types. In effect it works as four different analyzers each with different set-ups of inputs, filter bandwidths, averaging times, display modes, etc. Measurement Type is chosen in the Measurement Type menu (page 1 of the Main menu). Different Spectrum Types can be displayed depending on the Measurement Type. The relation is shown in Table 5.1.

The first four Spectrum Types in Table 5.1 are measured simultaneously as the analyzer has four input buffers. These Spectrum Types are saved in the memory. The rest are calculated, either in real-time or when a spectrum is recalled to the display.

Measurement Type	Spectrum Type 1	2	3	4	5	6	7	8	9	10
1 Ch.	Auto A	–	–	–	–	–	–	–	–	–
2 Ch.	Auto A	Auto B	–	–	–	–	–	–	–	–
Intensity	Mean P	Velo. V	Reac. J	Int. I	Pha.①	Mag.	Coh.①	Auto A③	Auto B③	–
Cross	Auto A	Auto B	Cross RE	Cross IM	Pha.②	Mag.	Coh.②	H1	H2	H3

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① Phase/coherence between mean pressure and particle velocity
② Phase/coherence between real and imaginary part of cross spectrum
③ Only displayed during measurement. Not available for recall

Table 5.1 Measurement Types and available Spectrum Types

5.3 The Six Analysis Modes

There are six different analysis modes. These are determined by the settings in the Filter Bandwidth and Trigger Multimode menus:

Analyzer Settings		Analysis Mode 1	2	3	4	5	6
Trigger Mode	Inactive	x	x				
	Active			x	x	x	x
Filter Bandwidth	Real-time	x		x	x		x
	Pass		x			x	
Multi-spectrum Type	Normal			x			
	Gated				x	x	
	Matrix						x

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Table 5.2 Analyzer settings for different analysis modes

1. **Simple Real-time Analysis**: One composite spectrum (see below) is measured in real-time. This analysis mode is described in section 5.3.1.

2. **Simple Multi-pass Analysis**: One composite spectrum is measured in passes. This analysis mode is described in section 5.3.2.

3. **Normal Multispectrum Analysis**: One multispectrum (see below), consisting of several composite spectra, is measured. This analysis mode is described in section 5.3.3.

4. **Gated Real-time Analysis**: One multispectrum is obtained by measuring and averaging several multispectra. This analysis mode is described in section 5.3.4.

5. **Gated Multi-pass Analysis**: One multispectrum is obtained by averaging several multispectra measured in passes. This analysis mode is described in section 5.3.5.

6. **Matrix Multispectrum Analysis**: One multispectrum, consisting of several composite spectra, is measured and arranged in a row-column-direction system. This analysis mode is described in section 5.3.6.

Data Structure Terminology

The **multispectrum** is the most complex data structure in the 2144. A multispectrum consists of one or (usually) more composite spectra.

A **composite spectrum** is called so because it consists of one or more spectra, the number of spectra depending on the Measurement Type used. In single channel analysis, the composite spectrum consists of only one spectrum – the A-channel autospectrum. In, for example, cross spectrum analysis, the composite spectrum consists of 4 spectra – A- and B-channel autospectra plus real and imaginary part of the cross spectrum. The 6 other spectra (see Table 5.1) are calculated on the basis of the composite spectrum and can be displayed in real-time in Measurement Mode.

5.3.1 Simple Real-time Analysis

Real-time analysis on the 2144 is defined as being 100% data analysis with no data loss in any frequency band of the spectrum. The Filter Bandwidth menu indicates whether the selected analysis can be carried out in real-time.

Real-time analysis is started by entering Measurement Mode and pressing **Averaging Control "Start"**. With exponential averaging selected, the analysis will continue until it is manually stopped. With linear averaging selected, the analysis will continue until the selected averaging time has elapsed, after which the analysis is automatically stopped.

Any ongoing analysis can be stopped by pressing **Averaging Control "Stop"**. Note that since the 2144 uses true L_{eq} averaging, it always displays calibrated results, irrespective of whether the selected averaging conditions have been met.

To restart an analysis, at the same time clearing the averaging buffer, press **Averaging Control "Start"**. To continue an analysis without clearing the averaging buffer, press **Averaging Control "Proceed"**.

Pressing **"Main Menu"** in Measurement Mode automatically stops any ongoing analysis. The current result is stored and, provided no measurement parameters have been changed, is returned to the screen when Measurement Mode is re-selected.

Menu text (page 2)

The spectrum hold function(s) can be defined in the Hold menu and is activated by using **"F3"** (see below).

The next free file number in the memory is displayed in the field next to **"F4"**. By pressing **"F4"** you save the measured data in that file. Alternatively, a file number can be entered using the numeric keys.

Using the Spectrum Hold Function

One or two hold functions can be applied to a real-time measurement, depending on the choice of Measurement Type. The hold functions are defined in the Hold menu. When a hold function is

activated (by pressing **"F3"**), it operates irrespective of whether there is an analysis in progress or not. When using Minimum Hold, it is therefore important to start the analysis before activating the hold function.

Any hold function is automatically disabled when the 2144 is taken out of Measurement Mode. Therefore, if the current results are needed again, it is important to save them in memory before leaving Measurement Mode.

Filter Settling in Real-time Analysis

In order to reduce power consumption, the digital filters of the 2144 do not start to operate until **"Meas. Mode"** is pressed. This means that if **Averaging Control "Start"** is pressed immediately after Measurement Mode is entered, the analyzer waits for the filters to settle before starting to average data, in order to avoid measurement errors. The measurement status shows the message SETTLING. Averaging first begins when the measurement status changes to RUNNING.

The amount of time allowed for the filters to settle depends on the setting of the Lowest Reliable Frequency entered using soft key **"F6"** in the Filter Bandwidth menu, and increases with decreasing frequency. It is therefore recommended to set Lowest Reliable Frequency as high as possible in relation to the requirements of the analysis, so that unduly long settling times can be avoided.

When analysis is required down to a frequency where the settling time begins to become significant, but where it is also desired to avoid any delay at the start of the analysis, data can be collected as a normal multispectrum using manual trigger (see section 5.3.3). In this case, filter settling starts as soon as **"Meas. Mode"** is pressed, but the analysis first starts when **Trigger "Manual"** is pressed. Therefore, provided the filters have settled by the time of the first trigger (averaging status is WAITING), there will be no delay at the start of the analysis.

5.3.2 Simple Multi-pass Analysis

Multi-pass analysis is used to extend the frequency range of 1/12- and 1/24-octave analysis on the 2144. Manual or auto-pass analysis is

selected in the Filter Bandwidth menu. Operation is identical with real-time analysis, with the following exceptions:

1. *Manual operation* can proceed with either linear or exponential averaging selected. To start the first pass of the analysis, enter the pass number by using **"F7"** and press **Averaging Control "Start"**. The following passes are started by entering the pass number and pressing **Averaging Control "Proceed"**. With linear averaging, each pass will automatically stop when the chosen averaging time has elapsed. With exponential averaging, each pass must be stopped manually. This process is repeated for all passes until the analysis is complete.
2. *Automatic operation* requires the use of linear averaging. The analysis is started by pressing **Averaging Control "Start"** and proceeds automatically to completion.
3. Automatic operation allows the use of triggering to start each pass of the analysis. This is achieved by collecting the data as a gated multispectrum, see section 5.3.4 for details.

Menu text (page 2)

The `Pass Mode` field (next to **"F7"**) shows manual or automatic operation and the pass number of the analysis, see Fig. 5.2. In manual operation, the pass number is entered in this field.

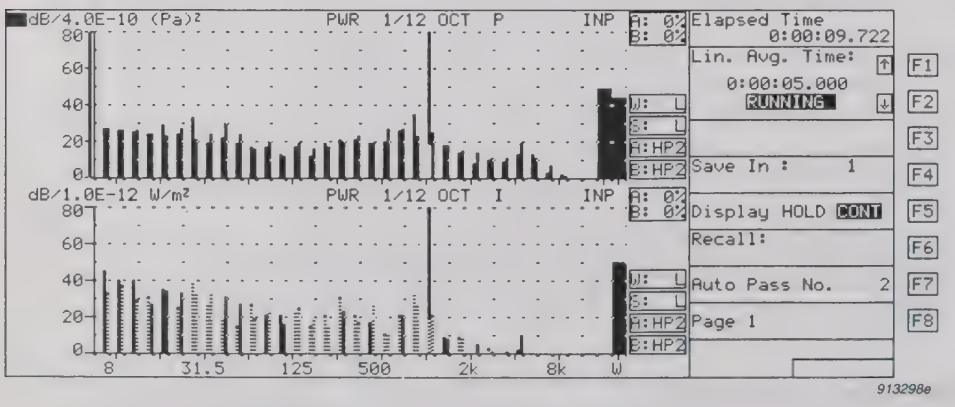


Fig. 5.2 A typical 2144 screen display in multi-pass analysis

The saving of data is the same as for Simple Real-time Analysis.

Filter Settling in Multi-pass Analysis

The comments about filter settling in real-time analysis also apply to multi-pass analysis, where the filters now have to settle between the passes of the analysis if errors are to be avoided. Again, the settling time is determined by the Lowest Reliable Frequency entered in the Filter Bandwidth menu, where the time interval between passes is calculated and displayed. Unlike real-time analysis, there is no convenient way of avoiding the filter settling time in multi-pass analysis.

5.3.3 Normal Multispectrum Analysis

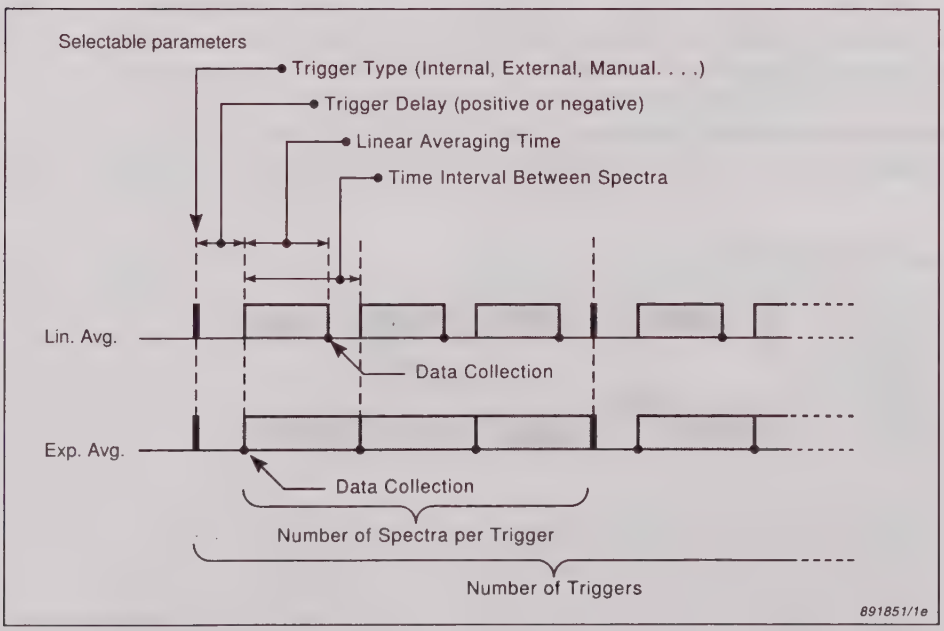


Fig. 5.3 Selectable parameters in collection of normal multispectra

Normal multispectrum is mainly used for analysis of non-stationary events. A series of spectra can be recorded versus time (or a time

dependent parameter) and stored in the multispectrum at a rate down to 1000 spectra/second (single channel operation).

Menu Text (page 2)

In order to be able to save a multispectrum, a file must first be opened by pressing **"F4"** `Open File No.` When the measurement is finished, the file is automatically closed and the field informs you how many spectra were saved.

"F3" (`Terminate Averaging and File`) is used for interrupting the collection of a multispectrum. For example, you do not always know beforehand how many spectra you need in a multispectrum. Pressing **"F3"** during a multispectrum measurement causes the file to be closed immediately and the data to be saved.

As a rule, data is protected after a save but it *is* possible to overwrite a multispectrum immediately after it has been closed simply by re-opening it (**"F4"**) using the same file number. This facility is included mainly for convenience; if you have saved an erroneous multispectrum, then you do not have to leave Measurement Mode to delete it.

Collection of Normal Multispectra

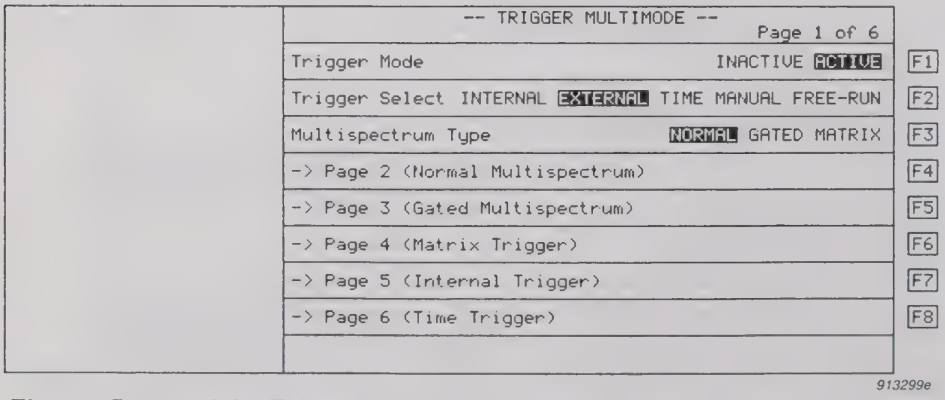

-- TRIGGER MULTIMODE --
Page 1 of 6
Trigger Mode INACTIVE ACTIVE F1
Trigger Select INTERNAL EXTERNAL TIME MANUAL FREE-RUN F2
Multispectrum Type NORMAL GATED MATRIX F3
-> Page 2 (Normal Multispectrum) F4
-> Page 3 (Gated Multispectrum) F5
-> Page 4 (Matrix Trigger) F6
-> Page 5 (Internal Trigger) F7
-> Page 6 (Time Trigger) F8
913299e

Fig. 5.4 Page 1 of the Trigger Multimode menu used for selection of the trigger and multispectrum type

Fig. 5.3 summarises the parameters selectable in collection of a normal multispectrum. The averaging mode and time are set in the Averaging menu or in Measurement Mode. The rest are selected using the Trigger Multimode menu.

1. Call up page 1 of the Trigger Multimode menu (see Fig. 5.4) by selecting page 2 of the Main menu and pressing **"F4"**.
2. Use **"F1"** to set the Trigger to ACTIVE (Trigger Multimode only operates when the Trigger is set to ACTIVE).
3. Use **"F2"** to select the type of trigger and **"F3"** to select NORMAL multispectrum.

Page 2 of the Trigger Multimode menu (see Fig. 5.5) is used to set the trigger delay (**"F1"**), the number of spectra per trigger (**"F2"**), the time interval between spectra (**"F3"**), and the number of triggers (**"F4"**). The maximum number of, for example, 1/3-octave autospectra which can be collected into a normal multispectrum is 999. The minimum time interval between spectra is 1 ms in exponential averaging (single channel operation) and equal to the selected averaging time in linear averaging. The maximum pre-trigger delay is 34 spectra for 1/3-octave bandwidth.

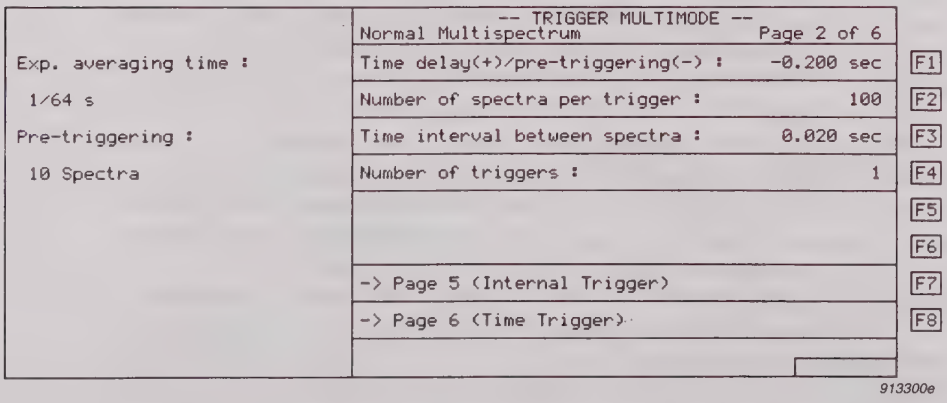


Fig. 5.5 Page 2 of the Trigger Multimode menu used for setting up a normal multispectrum

4. Press **"F5"** to call up page 2 of the Trigger Multimode menu and set up the parameters according to Fig. 5.3 and the description above.

Where an internal or real-time clock trigger is being used, it will be necessary to access the pages of the Trigger Multimode menu controlling these functions. These can be accessed from pages 1, 2, or 3 of the Trigger Multimode menu by pressing **"F7"** or **"F8"**, respectively.

5. Switch to Measurement Mode page 2 when the multispectrum has been set up.
6. Press **"F4"** (`Open File No.:`) to open a file in which to receive the multispectrum.

   Note that a file can only be opened when the measurement status is showing `READY`. If it does not, press **"F3"** (`Terminate Averaging and File`).

7. Press **Averaging Control "Start"** to start the measurement.

Viewing Multispectra

A single spectrum in a multispectrum can be viewed in Measurement Mode by keying-in its file number `FFF.III` (`III` is the index number, the position in the multispectrum) and using the `Recall` function.

A more convenient way, however, is to use the Data View menu. This menu allows you to recall a file, `FFF`, containing an entire multispectrum which can then be viewed from two directions: level/phase versus frequency bands (you can scroll through the index numbers) or level/phase versus index numbers (you can scroll through the frequency bands).

Hints for Setting Up Normal Multispectra

Many of the parameters used to set up normal multispectra are interactive. Therefore, where the 2144 will not allow you to enter the parameter value you wish, it might be because of some other parameter setting. In this case, you must check the rest of the set-up.

If linear averaging is selected, you may find that the 2144 will not let you enter the time interval you wish because it is shorter than the selected linear averaging time. For this reason it is usually more flexible to have exponential averaging selected when setting this parameter, since there will then be no limitation on its value and since the desired averaging conditions do not have to be chosen at this point. It will always be possible to set the desired averaging conditions in Measurement Mode prior to opening the file for collection of the multispectrum.

It is possible to check the functioning of a set-up for normal multispectrum collection by going to Measurement Mode and pressing **Averaging Control "Start"** without first opening a file. The collection will proceed but the results will not be saved. This gives you the opportunity to check trigger levels and so on. When the checks are complete, the measurement status can be returned to READY by pressing **"F3"**.

Examples of Use

The following gives some examples of use of normal multispectrum in the collection of data:

Collection of Data as a Function of a Third Parameter, such as RPM, Distance along a Test Track, etc.
Select normal multispectrum with external trigger, one spectrum/trigger, the number of triggers equal to the required number of spectra, and linear or exponential averaging. With exponential averaging, the current average is saved into the multispectrum with each external trigger, while with linear averaging, each external trigger starts a linear average which will be saved into the multispectrum on completion of the average.

Collection of Data Describing Non-stationary Events
Select normal multispectrum with internal, external or manual trigger depending on the type of data to be collected. Internal triggering is used where triggering is to be from the event itself (a gun shot, for example) and external triggering is used where it is to be from some stimulus associated with the event (for example a car passing a photo detector). In such data collection, a negative trigger delay is often used to capture pre-trigger information. Select linear or exponential averaging with a small enough averaging time to be able to follow the event (but remember that the BT product must be greater

than or equal to 1) and a time interval between spectra to give sufficient resolution to describe the time variation of the event. Select enough spectra to describe the entire event. Select one trigger to record one event and more than one trigger to record more than one event.

Collection of Data at Regular Time Intervals
Select a normal multispectrum with a time trigger. Use the Time Trigger (page 6 of the Trigger Multimode menu) to select the time to start data collection and the time interval between triggers. Select either linear or exponential averaging with the number of spectra/trigger equal to the number of spectra required to be collected at each time interval, and the number of triggers equal to the required number of time intervals. The Standby mode of the 2144 can also be used for this type of data collection (see Chapter 8).

Collection of a Series of Random Events
Select normal multispectrum with an internal trigger. Linear or exponential averaging can be used. Exponential averaging has the advantage that the setting of the elapsed time counter, which is saved with each spectrum, will give the time at which each spectrum is saved relative to the start of the measurement giving total documentation of the result. Set the number of triggers equal to or greater than the number of events expected. Set the number of spectra/ trigger equal to 1 if each event is to be characterized by a single spectrum and more than 1 if each event is to be characterized by a multispectrum.

5.3.4 Gated Real-time Analysis

Gated multispectrum measurements are used for repetitive events such as noise or vibrations from rotating machines. For gated measurements, `Multispectrum Type` on page 1 of the Trigger Multimode menu must be set to `GATED`. Often, external trigger is used with a tacho signal as trigger input. Collection of a gated multispectrum is similar to the collection of a normal multispectrum except that there are now always multiple triggers. The multispectra (one for each trigger) are then averaged together spectrum for spectrum to form a resulting average multispectrum across all of the triggers. The process is illustrated in Figs. 5.6 and 5.7.

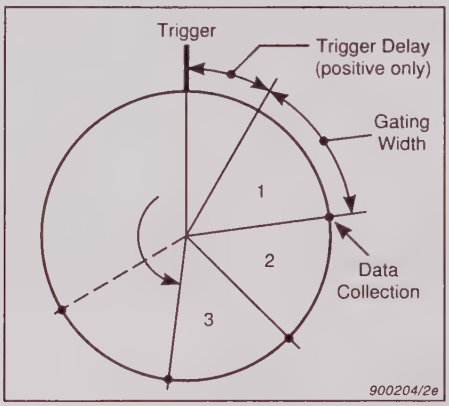


Fig. 5.6 A measurement cycle in the collection of a gated multispectrum

Collection of Gated Multispectra

Collection of a gated multispectrum is started by entering Measurement Mode and pressing **Averaging Control "Start"**. Unlike normal multispectrum measurement, it is not necessary to open a file to receive the multispectrum. During data collection, **"F3"** (on page 2 of the menu text) can be used to select a particular spectrum within the multispectrum to monitor the progress in the measurement.

Menu Text (page 2)

The `Monitor Spectrum No.` field is used if you wish to monitor one particular spectrum in a trigger cycle during measurements. The spectrum number is keyed-in and entered using **"F3"**. Otherwise, a "0" is entered for the spectrum number; "0" denotes the input buffer and you monitor all the measured spectra.

On completion of the measurement, the gated multispectrum can be saved by pressing **"F4"** (`Save In:`). The multispectrum can be viewed in the same way as described under normal multispectrum analysis (section 5.3.3).

Example:

Collection of Data from Rotating Machines Using a Tacho Probe

Select Gated Multispectrum with external triggering. If, for example, the tacho probe sends one trigger signal for each revolution, set the gating width to 60/rpm (= seconds per revolution) divided by

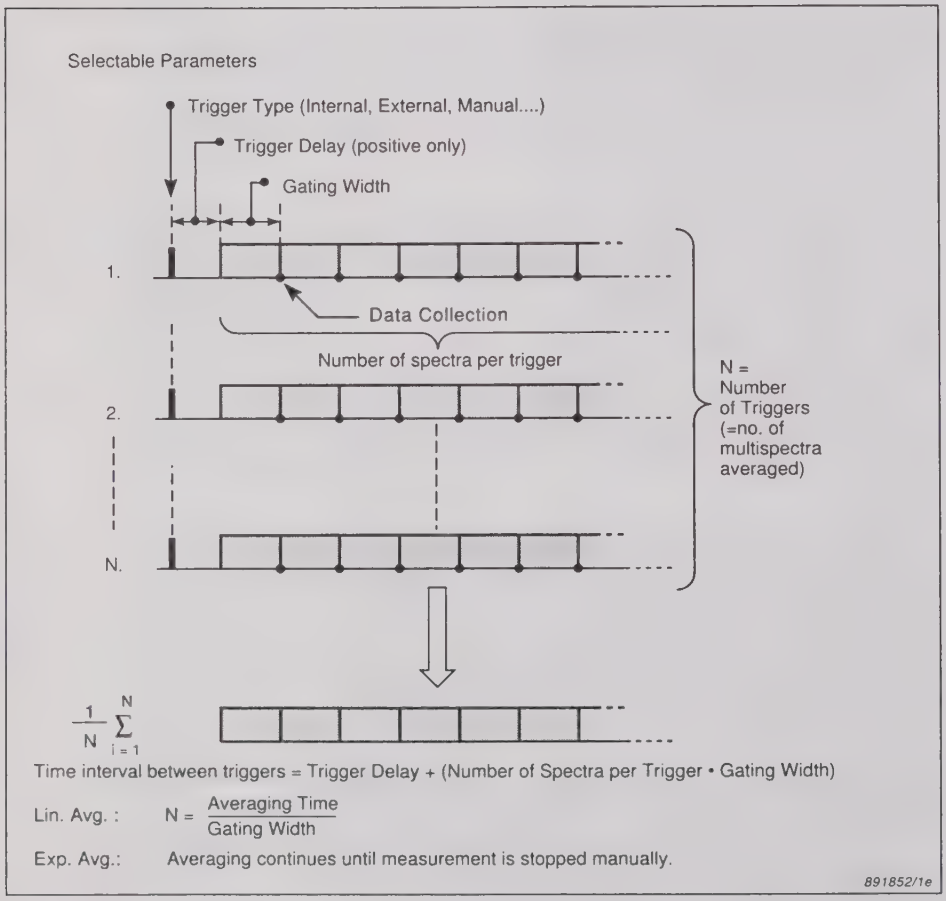

Selectable Parameters
Trigger Type (Internal, External, Manual....)
Trigger Delay (positive only)
Gating Width
1.
Data Collection
Number of spectra per trigger
2.
N.
N = Number of Triggers (=no. of multispectra averaged)
$\frac{1}{N}\sum_{i=1}^{N}$
Time interval between triggers = Trigger Delay + (Number of Spectra per Trigger • Gating Width)
Lin. Avg. : $N = \frac{\text{Averaging Time}}{\text{Gating Width}}$
Exp. Avg.: Averaging continues until measurement is stopped manually.
891852/1e

Fig. 5.7 Parameters selectable in the collection of a gated multispectrum

the number of spectra per trigger. Set the linear averaging time equal to the gating width multiplied by the required number of averaged multispectra.

5.3.5 Gated Multi-pass Analysis

Multi-pass analysis (see section 5.3.2) can also be used with gated measurements. In this case, there are multiple trigger cycles for each pass. In manual pass mode, the Averaging Status field reads

FINISHED when each pass has been completed. Otherwise, the same comments apply as for gated real-time analysis.

5.3.6 Matrix Multispectrum Analysis

Matrix Multispectrum is a special version of Normal Multispectrum; Number of spectra per trigger is always 1, and the number of triggers is determined by the specified number of row, columns, and directions. Averaging is linear, only.

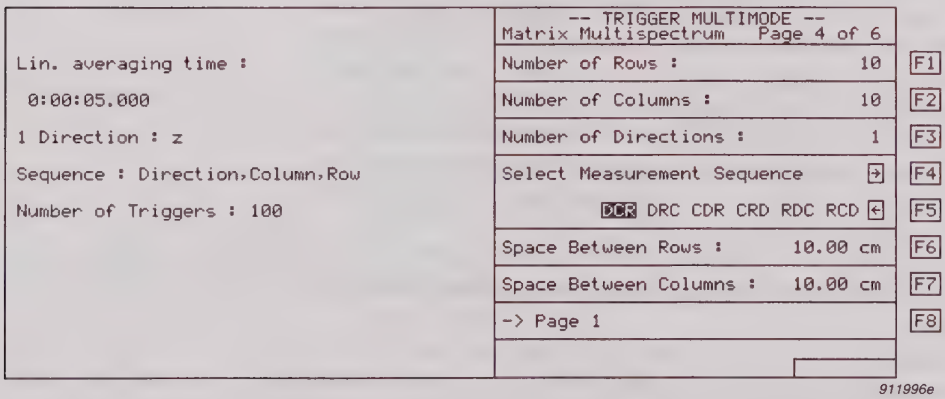


Fig. 5.8 Menu for setting up parameters for a matrix multispectrum

When you key-in the number of directions for each measurement point (see Fig. 5.8), the corresponding directions are displayed on the left-hand side of the screen. The z-axis is perpendicular to the surface enclosing the measurement object.

Menu Text (page 2)

The Open File No. and Terminate Averaging and File fields are described in section 5.3.3. However, a special function has been included in Matrix Multispectrum mode: when a file is opened (by pressing **"F4"**) the text Open File No. changes to Delete Last Spec. This gives a convenient way of deleting the last measured spectrum if a measurement fails. You can not delete the last, for example, three spectra by pressing **"F4"** three times.

The field next to soft key **"F7"** gives information about which row, column, direction is to be measured next. The field is not interactive and is updated automatically as the measurement proceeds.

Examples of Use

The following gives some examples of use of matrix multispectrum in the collection of data:

Collection around an Array of Measurement Points, for example Sound Power Determination

Select matrix multispectrum with a manual trigger and define a measurement grid by keying-in the number of rows and columns. For each measurement point, specify the number of probe directions. It will then be possible to go from measurement point to measurement point using a manual trigger to start the measurement at each point. Use of a manual trigger allows an indefinite pause between each measurement allowing the probe to be moved to the next measurement point. The sound power calculation itself can be made using the Spectrum Calculator menu (see section 9.1.2). See section 5.4 on how to use the probe and remote control.

Collection of Sound Power Data using Swept Sound Intensity Measurements

Select matrix multispectrum with a manual trigger and set the number of both rows and columns to 1. Usually, only one probe direction is used. Set the linear averaging time equal to the sweep time of one surface.

5.4 Sound Intensity Probe Type 3548

The 2144 is designed to work with Sound Intensity Probe Type 3548 and has an 18-pin socket on the rear panel for single-cable connection (see section 3.2). Remote Control Handle ZB 0017, which is a part of Type 3548, is shown in Fig. 5.9.

The ZB 0017 has four buttons which correspond with hard keys on the 2144:

Fig. 5.9 Remote Control Handle ZB 0017 of Sound Intensity Probe Type 3548

"Start Averaging": If the 2144 is set up for Matrix Multispectrum with manual trigger, this button corresponds with the **"Manual Trigger"** hard key on the 2144.

"Accept Save": Has the same function as the **Averaging Control "Stop"** hard key on the 2144.

"Input Autorange": Has the same function as the **"Autorange"** hard key on the 2144.

"Autosequence": Corresponds with the **Autoseq. "Stop/Step"** hard key on the 2144 and is used for executing an autosequence.

Hints for Use

For a standard sound intensity measurement the analyzer should be set up as described in the first example in section 5.3.6. The file is opened by pressing **"F4"** on page 2 in Measurement Mode and the measurement is started by pressing **Averaging Control "Start"** on the analyzer. When you have done that, Averaging Status will be WAITING for a trigger. You can then measure a spectrum at each measurement position by pressing **"Start Averaging"** on the remote control.

A measurement sequence can be stopped manually by pressing **"Accept Save"** on the remote control. To restart the measurement, **"Start Averaging"** is pressed twice: the first time to set the analyzer WAITING, and the second time to trigger the first measurement.

It can be quite convenient to use the remote control in connection with autosequences. An example of a short, commonly used autosequence is shown in Chapter 8. The sequence deletes the last mea-

sured spectrum when you press **"Autosequence"** on the remote control. You could also write a sequence that terminates averaging and saves the multispectrum.

Chapter 6

Memory

6.1 Saving Measurement Data 6–2

Data Memory/Disk Memory 6–2
File Management 6–3
Data Transfer 6–4

6.2 Measurement Text 6–5

6.1 Saving Measurement Data

6.1.1 Data Memory/Disk Memory

All measurement data can be saved in the internal data memory or on disk. The file structure used for saving data is common to both. Measurement data is first saved in the data memory (for example by pressing key **"F4"** in Measurement Mode) from which it can be transferred to disk. Likewise, measurement data can be transferred from disk to data memory.

The data memory and disk are controlled through the Memory menu which is accessed by pressing **"F7"** on page 2 of the Main menu. Page 1 of the Memory menu is common to both. Pages 2 and 3 apply to the memory type selected on page 1 (in the `Select Memory` field).

NOTES:

- The disk-drive of the 2144 is designed for use with both high density (HD) and double density (DD) disks. DD disks must be used for compatibility with, for example, Brüel & Kjær Frequency Analyzer Type 2123 or 2133 and some computers which use double density disks only.

- In order to save power, the 2144 switches off the analogue input module when the disk-drive is in use. When making measurements using a microphone requiring a polarization voltage, it is therefore advisable to wait for 1 or 2 minutes after any operation involving use of the disk-drive before proceeding with measurements.

Storage Capacity

2144 measurement data is saved into files. One file can contain a single spectrum or a multispectrum. The file also contains the measurement set-up used when the data was saved. Both the data memory and DD disks hold a maximum of 111 files, HD disks hold up to 223 files (when formatted on the analyzer). In addition, the following gives some examples of the maximum number of sound intensity spectra (measured in real-time) which can be saved in the data memory:

1/1-octave : 1203 spectra
1/3-octave : 541 spectra
1/12-octave : 178 spectra
1/24-octave : 99 spectra

The total capacity of the 2144 internal data memory depends on which limitation is reached first, the maximum number of files or the maximum number of spectra. The total capacity of the disk usually depends on the size of the files being stored, and could be anything from 223 spectra (1 spectrum per file) up to many thousands of spectra (many spectra per file).

6.1.2 File Management

Identifying Files in Data Memory or on Disk

A file list of the data memory or disk can be obtained by selecting page 2 of the Memory menu. When the `Select Memory` field on page 1 is set to `SPECTRUM`, the files in data memory are listed. If the field is set to `DISK`, the files on the disk are listed. In either case, each file is identified by its name (a 3-digit number), whether or not it is protected, the type of data in the file, the filter bandwidth, and the time at which it was saved (according to the analyzer's internal clock). For a normal multispectrum, the time indicates when the measurement was started.

Deleting Files

The general method of deleting files is through page 2 of the Memory menu. Protected files (labelled with a `P`) cannot be deleted and must have their protection changed first.

The only exception to the above procedure is when the 2144 is in Measurement Mode and is set to collect normal multispectra. In this case, it is possible to manually re-enter the number of the last file saved, and re-open that file. The next normal multispectrum collected will be overwritten into that file (see section 5.3.3).

All files in the data memory can be deleted at one time by pressing **"F5"** on page 1 of the Memory menu. The decision needs to be confirmed within about 5 seconds by pressing **"F4"**, otherwise nothing will happen.

6.1.3 Data Transfer

Transfer Between Data Memory and Disk

Data transfer between data memory and disk is controlled from page 3 of the Memory menu. When the `Select Spectrum` field on page 1 of the Memory menu is set to `SPECTRUM`, data is transferred from data memory to disk. When the field is set to `DISK`, data is transferred from disk to data memory. Single files can be transferred by placing the cursor on the required file and setting `No. of Files to Transfer` to 1. Blocks of files can be transferred by placing the cursor on the first file and specifying how many files are to be transferred. In either case, the transfer is commanded by pressing **"F4"** (`Copy to Data Memory/Disk`).

Copying Comma Delimited Files

Measurement data can be copied to disk in comma delimited format:

1. Select `DATA` memory by pressing **"F1"** on page 1 of the Memory memory.
2. Press **"F8"** to go to page 3 (data transfer).
3. Use **"F1"** and **"F2"** to select a file to copy.
4. Press **"F8"** to convert the file format and copy the file to disk.

The comma delimited file can be identified in a directory by its extension `TXT`, for example `001.TXT`.

This format enables a computer to handle the data so that it can be presented in tabular or graphics form such as spreadsheets. The format is compatible with Lotus 1-2-3.

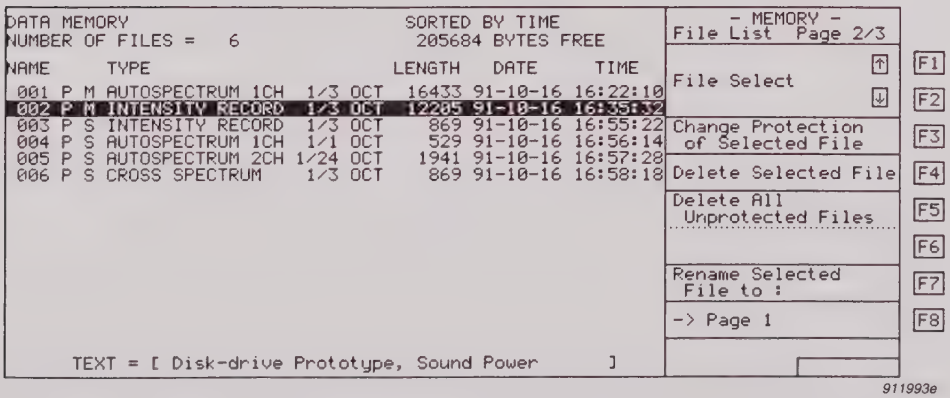
Back-up of Measurement Data

No non-volatile memory is 100% non-volatile in all situations; electrical shocks, such as static electricity, can erase the memory or a part of it. Therefore: **always make a back-up of your results on disk** before you switch the analyzer off.

6.2 Measurement Text

Additional identification can be given to files using the Measurement Text menu on page 2 of the Main menu. This allows up to 8 different lines of alphanumeric text, each up to 40 characters long, to be defined. One of these lines can then be selected and appended to a particular file. The line of text is then displayed at the bottom of the screen when the cursor is placed on the corresponding file, see Fig. 6.1. It is also displayed in Measurement Mode below the x-axis of a Single Display. The addition of measurement text can only take place when the file in question is in the data memory. It will, however, be copied to disk (or back to the data memory) along with the rest of the file in a data transfer.

Entry of numeric values, for example measurement position numbers, is easy since the numeric keys on the front panel can be used. Entering alphanumerics, however, can be a laborious process. In practice, it will therefore be usual to write the text on a PC and then reading it in over one of the analyzer's interfaces. This can be done either in advance of measurements or, where more than 8 text labels are required, during measurements as shown in the following example.


DATA MEMORY
NUMBER OF FILES = 6
SORTED BY TIME
205684 BYTES FREE
NAME TYPE LENGTH DATE TIME
001 P M AUTOSPECTRUM 1CH 1/3 OCT 16433 91-10-16 16:22:10
002 P M INTENSITY RECORD 1/3 OCT 12285 91-10-16 16:35:32
003 P S INTENSITY RECORD 1/3 OCT 869 91-10-16 16:55:22
004 P S AUTOSPECTRUM 1CH 1/1 OCT 529 91-10-16 16:56:14
005 P S AUTOSPECTRUM 2CH 1/24 OCT 1941 91-10-16 16:57:28
006 P S CROSS SPECTRUM 1/3 OCT 869 91-10-16 16:58:18
TEXT = [Disk-drive Prototype, Sound Power]
- MEMORY -
File List Page 2/3
File Select
F1
F2
Change Protection of Selected File
F3
Delete Selected File
F4
Delete All Unprotected Files
F5
F6
Rename Selected File to :
F7
-> Page 1
F8

911993e

Fig. 6.1 A file list with measurement text being used to add indentification

Example: Field Use with Lap-top Computer

50 measurements must be made in the field and all data files must be labelled with different text. A lap-top computer set up to communicate with the 2144 is available. A convenient working procedure would be:

1. Call up the Measurement Text menu on the 2144.
2. Press **"Meas. Mode"**.
3. Make a measurement and save the file in the data memory.
4. Press **"Prev. Page"** to go back to the Measurement Text menu.
5. Write the text string on the computer and transfer it to the 2144 (consult the interface manual on how to do this). Use the same text field every time you do this.
6. Using the 2144, key-in the number of the file you saved in step 3 and press **"F7"** (copy text to file).
7. Go back to step 2 and repeat the procedure for the rest of the measurements.

Chapter 7

Preselected Set-ups

7.1 Factory-defined Set-ups 7–2

7.2 User-defined Set-ups 7–2

7.1 Factory-defined Set-ups

Type 2144 has 8 complete factory-defined set-ups: 4 for acoustic measurements (one for each Measurement Type) and 4 for vibration measurements. 2-channel analysis is default after Master Reset.

Selecting a Factory-defined Set-up

Set-ups are recalled from the internal memory in three parts, the MEASUREMENT set-up, the DISPLAY set-up and the CALIBRATION set-up. This allows you to decide how much of a particular set-up to recall. Only the activated parts of the preselected set-up override the current set-up. This way you can use, for example, a standard calibration set-up without ruining the measurement set-up you are currently working with.

1. Go to the Preselected Set-up menu on page 3 of the Main menu.
2. Select VIBRATION or ACOUSTIC using **"F3"**.
3. To activate the chosen set-up (or part of it), press **"F4"**, **"F5"**, and/or **"F6"** and leave the menu.

7.2 User-defined Set-ups

Up to 4 user-defined set-ups can be saved in the analyzer's non-volatile memory. Thus, you have instant access to complete set-ups that you use frequently.

Saving a Set-up

1. Specify the set-up parameters through the menu system.
2. Go to the Preselected Set-up menu on page 3 of the Main menu.
3. Press **"F1"** to select the location number at which you want to save the set-up.
4. Press **"F3"** to save the set-up.

Recalling a Saved Set-up

1. Go to the Preselected Set-up menu on page 3 of the Main menu.

2. Press **"F1"** to select the location number from which you want to recall the set-up.
3. Select SAVED set-up using **"F3"**.
4. To activate the chosen set-up (or part of it), press **"F4"**, **"F5"**, and/or **"F6"** and leave the menu.

Recalling a Set-up from Disk File

Whenever the 2144 stores data on disk, the current set-up used for the measurement is always stored along with the data. This therefore provides a means of storing set-up data on disk (or in data memory). The set-up data stored as part of a disk file can be called into the active set-up as follows:

1. Transfer a file with the required set-up from disk to data memory (see section 6.2).
2. Go to the Preselected Set-up menu on page 3 of the Main menu.
3. Set Recall Reference Set-up to ACTIVE using **"F7"**.
4. Go to Measurement Mode.
5. Key-in the file number of the set-up and enter it using **"F8"**.

The set-up is now displayed but the display is in HOLD mode (see the Avg. Status field).

6. Press **"F8"** to select text page 2 and press **"F5"** to set the display in CONT mode.

When the **Averaging Control "Start"** key is pressed, the measurement is made using the recalled set-up.

Chapter 8

Autosequence

8.1 Autosequence Set-up 8–2

8.2 Programming and Executing an Autosequence 8–2

8.3 Editing an Autosequence 8–4

8.4 Standby Mode 8–5

8.1 Autosequence Set-up

Measurements can be automated by using the pushkey autosequence facility in the 2144. A total of 4 autosequences, each consisting of maximum 200 keypushes, can be saved in the analyzer's memory. An autosequence can include any procedure that can be performed manually by using pushkeys on the front panel of the analyzer. Autosequences are used where a measurement procedure is very long, where a sequence of keypushes must be repeated many times, or where measurements must take place without the operator's presence.

The analyzer's set-up (including the field selector positions) is saved with the autosequence when you start the programming. You have the choice between using this "initial" set-up or the analyzer's current set-up when you run the autosequence. The way to do this is to set `Recall Current Autosequence Set-up upon Execution` to `ON` or `OFF`, respectively (**"F7"** in the Autosequence menu). In the first case, the autosequence always starts from the same set-up, which makes it easier to do the programming. Sometimes, however, it is more convenient to start a new autosequence where the previous one ended, especially where you want to execute a series of short sequences. The only exceptions to the above are the I/O Interface and Calibration set-ups which are not saved with the autosequence.

To make the autosequence as short as possible, the analyzer should always be set up for the first measurement before you start the programming.

8.2 Programming and Executing an Autosequence

The programming of an autosequence in the 2144 very much resembles that of a pocket calculator: first the sequence is executed manually step by step and then the analyzer is able to repeat it. The general procedure for programming an autosequence is this:

1. Select the Autosequence menu on page 3 of the Main menu.

2. Set Learn Mode to `ON` by pressing **"F1"** (the **Autoseq.** LED comes on).
3. Press the required steps for the autosequence (max. 200 steps).
4. After the last step, press **Autoseq. "Stop/Step"**.

This terminates the programming, saves the sequence as the Current Autosequence and returns you to the Autosequence menu with Learn Mode `OFF`.

5. Use **"F7"** to choose whether or not the autosequence must start from its own set-up or from the analyzer's current set-up (see section 8.1).
6. Press **"F5"** to execute the current autosequence.

The Current Autosequence can also be executed by pressing the **Autoseq. "Stop/Step"** key (when Learn Mode is OFF). This means that you can execute an autosequence directly from any menu, including Measurement Mode.

Note: When you are programming (and editing, see section 8.3) an autosequence, soft key **"F4"** is not active in Measurement Mode (`Save` or `Open File No.`). Its function is, however, implemented when the autosequence is executed. The other way around, **Averaging Control "Stop"** is not implemented when the autosequence is executed even though it is pressed while the analyzer is in Learn Mode. This is an advantage when a sequence includes measurements with long linear averaging times.

Type 2144 automatically waits for an operation to be completed before executing the next step in an autosequence. Hence, there is no need to specify delays or wait states in the middle of a sequence.

Delay Before Execution

It is possible to delay the execution of the autosequence after **"F5"** or the **Autoseq. "Stop/Step"** hard key is pressed. The delay, which is entered using **"F6"**, can be up to 10 minutes long. The main purpose of this function is to allow the operator time to leave the measurement area before the measurements start. Another application is to allow the analyzer to settle after wake-up (see section 8.4).

Example: Use with Sound Intensity Probe Type 3548

The following autosequence is intended for use with matrix multispectrum and manual trigger (see section 5.3.6). The autosequence deletes the last measured spectrum in a measurement sequence. It is assumed that the analyzer is in Matrix Multispectrum mode:

1. Set Learn Mode `ON` by pressing **"F1"** in the Autosequence menu.
2. Press **"Meas. Mode"** followed by **"F8"** to go to Measurement Mode page 2.
3. Press **"F4"** to delete the last spectrum (this key-press is not executed now but will be when the autosequence runs. Also, the text reads `Open File No.` now but will read `Delete Last Spec.` when the autosequence is executed).
4. Press **Autoseq. "Stop/Step"** to exit Learn Mode and return to the Autosequence menu.
5. **"Recall Current Autosequence Set-up upon Execution** to `OFF` by pressing **"F7"**.

This autosequence is used in Measurement Mode the following way:

1. Press **"F4"** on Measurement Mode page 2 to open a file. Note that the text changes to `Delete Last Spec.`
2. Make measurements by pressing the **"Start Averaging"** button on the remote control handle of the probe.
3. When a faulty spectrum has been measured, execute the autosequence by pressing the **"Autosequence"** button.
4. Press the **"Start Averaging"** button to remeasure the spectrum.

8.3 Editing an Autosequence

The **Autoseq. "Stop/Step"** key can also be used for stepping through an autosequence. As **Autoseq. "Stop/Step"** is pressed, the screen pictures corresponding to each step appear on the display.

This function is mainly used when you want to locate an error or want to change anything. The general procedure is this:

1. Go to the Autosequence menu on page 3 of the Main menu.
2. Press **"F1"** to switch Learn Mode ON.
3. Press **Autoseq. "Stop/Step"** repeatedly to locate the first step that you want to change.
4. Go to the step immediately before that by stepping through the sequence again and re-enter the rest of the autosequence (see note below).
5. Press **Autoseq. "Stop/Step"**, this time to terminate the programming.

Note: The **Autoseq. "Stop/Step"** key only works as a "step" key as long as no other key is pressed. As soon as another key is pressed, the **Autoseq. "Stop/Step"** works as a "stop" key. For this reason, it is not possible to re-enter a single step in the middle of a sequence and then step on to the end of the sequence.

Deleting the last step(s)

1. Locate the step that you want to be the last by stepping through the sequence.
2. Go to the step immediately before that by stepping through the sequence again.
3. Repeat the step that you now want to be the last.
4. Press **Autoseq. "Stop/Step"**.

8.4 Standby Mode

The 2144 can execute an autosequence at any pre-set time. The sequence can be repeated any number of times (maximum is 9999 times) at fixed intervals.

The Wake-up Function

To prepare the execution of an autosequence in Standby Mode:

1. Go to the Autosequence menu on page 3 of the Main menu.
2. Recall the required autosequence to the Current Autosequence location.
3. Press **"F8"** to go to page 1 of the Real-time Clock menu.
4. Set the time for the first wake-up (remember to check that the analyzer's real-time clock is set correctly).
5. If more wake-ups are required, set the number of wake-ups and the time interval between them.
6. Press **"F7"** to activate the Wake-up function.

After approximately 10 seconds, the analyzer turns itself off and enters Standby Mode. This is indicated by the flashing **Standby** LED on the front panel.

Power-on After Wake-up

The 2144 switches itself on (wakes up) at the preset time and goes through the usual power-on self test (this takes approximately 30 seconds). It then goes directly to the Autosequence menu and executes the Current Autosequence after a possible delay has elapsed. When the autosequence has been executed, the analyzer returns to page 1 of the Real-time Clock menu with Wake-up `ACTIVE`. Wake-up must be switched to `INACTIVE` within about 10 seconds if you do not want the analyzer to go back to standby.

If the 2144 is switched on manually when it is in wake-up mode, the message `"Wake up" is active` appears during power on self test, and the analyzer goes directly to page 1 of the Real-time Clock menu with Wake-up `ACTIVE`. Wake-up must be switched to `INACTIVE` within about 10 seconds unless you want the analyzer to go back to standby.

Delay Before Execution

It is usually necessary to set a Delay Before Execution when the analyzer is to execute an autosequence in Standby Mode. This is to allow the analogue circuits time to stabilize. A delay of 2 minutes is appropriate.

Chapter 9

Post-processing

9.1 Spectrum Calculator 9–2

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9.2 Spectrum Weighting 9–5

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Weight Functions Based on Measurement Data 9–8

9.3 Spectrum Unit 9–8

9.4 Integration and Differentiation 9–8

9.1 Spectrum Calculator

The Spectrum Calculator menu has two main functions: one is intended for relatively simple arithmetic operations on measured data. Such operations could be background noise subtraction, calculation of attenuation, averaging of spectra (where the division by the number of spectra is made using dB subtraction), and so on. Spectrum arithmetic is described in section 9.1.1.

The other main function is sound power calculation. The calculation is based on either sound pressure or intensity data depending on the Measurement Type. Data must be arranged in a multispectrum (see section 5.3). Sound power calculation is described in section 9.1.2.

9.1.1 Spectrum Arithmetic

Although the Spectrum Calculator menu is intended for relatively simple calculations, it can also handle, through the use of autosequencing, much more complicated calculations where these can be broken down into a series of arithmetic operations and where they are of a repetitive nature. For details on autosequencing, see Chapter 8. If, during a calculation, the result in a band is over- or underrange, or, for instance, a negative power is obtained, the 2144 sets the result for that band to the upper or lower limit for the band in question, as appropriate.

Example: Background Noise Subtraction

Two spectra were measured: one of a source signal contaminated with background noise and one of the background noise only. It can be assumed that the background noise was stationary. To obtain the spectrum of the source signal:

1. Call up page 3 of the Spectrum Calculator menu.
2. Select Working Bandwidth equal to the bandwidth of the recalled spectra.
3. Go to page 4 by pressing **"F8"**.
4. Recall the spectrum containing the source signal to the upper display and the noise spectrum to the lower display using soft key **"F1"** and the **"Upper/Lower"** hard key.

5. Select PWR as calculation mode by pressing **"F5"**.
6. Press **"F7"** (Upper - Lower → Upper) to subtract the spectra.

The result is displayed in the upper spectrum and can be saved in a file in the data memory by using the **"Upper/Lower"** key and **"F1"** on page 3 of the menu. The type "CALC." is assigned to the file and displayed in a file list.

Note: The reference used in dB calculation mode always follows the upper display. This means that if the upper and lower spectra have different dB references, then the result of an addition depends on which spectrum is the upper and which is the lower.

Maximum Level Difference

Situations may occur where, due to an insufficient input level, one or more of the filters did not "wake up" during a measurement. The spectrum therefore contains very large negative dB values (–256 dB). Subtracting such a spectrum using dB subtraction, would render the overall result useless. To overcome this problem:

1. On page 4, select Upper or Lower display using the **"Upper/Lower"** key.
2. Key-in a value for Maximum Level Difference within the selected display (the allowed range is 0 to 100 dB).
3. Enter it by pressing **"F7"**.

This causes all the low-level frequency bands to be rounded up so that the maximum level difference within the spectrum is equal to the specified value.

Working Bandwidth

The Spectrum Calculator menu can also be used, for instance, for the calculation of 1/1-octave data from 1/3-octave data by selection of the appropriate working bandwidth. It is important to be aware of the difference between the original bandwidth of the recalled data and the working bandwidth that represents it in the Spectrum Calculator menu. The easiest way to see this is by looking at an example:

Example:
A spectrum was originally recorded in 1/3-octaves. The levels in the 800 Hz, 1 kHz, and 1.25 kHz bands are 33.7 dB, 34.1 dB, and 29.3 dB, respectively. If Working Bandwidth is set to **1/1**, these three levels are added to form the level of the 1/1-octave 1 kHz band which then becomes 37.6 dB (power adding). If, however, Working Bandwidth is set to **1/12**, the number of channels is quadrupled (power spreading) and therefore the level in what *appears* to be the 1 kHz band is 6 dB lower than the original.

9.1.2 Sound Power Calculation

Sound pressure and sound intensity data arranged in a multispectrum can be used as a basis for sound power calculations. The calculation is made on the whole multispectrum file or a specified part of it. While the calculation progresses, **CALCULATING** is displayed in the error field on the screen.

SPL Measurements

For SPL measurements, the analyzer calculates the sound power using the following equation:

$$L_W = <L_p> + 10\log_{10}\frac{S}{S_0}\,\text{dB}$$

where:

$<L_p>$ = the mean sound pressure level over the enclosing surface in dB re 20 μPa
S = enclosing surface area in m^2
S_0 = reference surface area (1 m^2)

Area Correction

The term $10\log_{10}(S/S_0)$ in the equation above is called the Area Correction and must be set **ON** if you want to calculate sound power. However, setting the area correction **OFF** provides a convenient way of calculating the mean spectrum for a multispectrum.

Sound Intensity Measurements

For sound intensity measurements, the analyzer calculates the sound power using the following equation:

$$L_W = L_I + 10\log_{10}\frac{S}{S_0}\,\mathrm{dB}$$

where:

L_I = Total intensity level summed over the enclosing surface in dB re 1 pW/m^2
S = enclosing surface area in m^2
S_0 = reference surface area (1 m^2)

9.1.3 File Modification

As an extra feature, the Spectrum Calculator menu (page 1) allows you to substitute spectra from one file to another. This is particularly useful if one of the measurements in a multispectrum fails, for example because of unwanted noise. If the measurement conditions allow it (that is if they are the same as when the multispectrum was measured), then that particular measurement can be made afterwards and substituted for the "contaminated" spectrum.

9.2 Spectrum Weighting

The Spectrum Weighting menu is used to add weight functions to the measured spectrum and, through the W-band, to the broadband data. However, it can also be used to subtract weightings out of measured data. For instance, an A-weighting could be subtracted out of measured data by inverting the weighting prior to its addition to the data. Such an inversion can be carried out using **"F5"** on page 1 of the Spectrum Weighting menu.

There are three ways of obtaining a weight function in the Spectrum Weighting menu:

- User-defined weightings can be entered on page 2 of the menu.
- Standard weightings are permanently available from the internal memory.
- Weight functions can be based on measurement data.

9.2.1 User-defined Weightings

Entering a User-defined Weighting

User-defined weightings are entered as a series of points, and the analyzer interpolates linearly between the points to produce the complete weight function. Where required, user-defined weightings can be used as masks. A total of four user-defined weightings can be entered and saved in the non-volatile internal memory in the following way:

1. Select the Spectrum Weighting menu on page 2 of the Main menu.
2. Press **"F8"** (`Page 2`).
3. Select the frequency at which weighting is required using **"F1"**, **"F2"**, and/or numeric input.
4. Key-in the desired weight level and enter it using **"F3"**.
5. Repeat steps 3 and 4 until all weight levels have been specified.
6. Save the weighting by keying-in the weighting number (1...4) and entering it using **"F8"**.

Saving User-defined Weight Functions and Reference Spectra as Files

Up to four user-defined weight functions or reference spectra can be saved in the non-volatile memory (as user weightings U1 to U4). If a larger number is required or if it is necessary to store them on disk, they must be made into files. This is done by using the Spectrum Weighting and Spectrum Calculator menus:

1. Call up the Spectrum Weighting menu from page 2 of the Main menu by pressing **"F5"**.
2. Use page 2 of the Spectrum Weighting menu to enter the user-defined weighting (see above). Where a reference spectrum is to be entered, enter it as if it were a user-defined weighting.
3. Use **"F8"** on page 2 of the Spectrum Weighting menu to save the user-defined weighting/reference spectrum in one of the four locations (U1 to U4) reserved for user-defined weightings.
4. Call up the Spectrum Calculator menu from page 3 of the Main menu by pressing **"F1"**.

5. Select page 4 of the menu and use **"F1"** and the **"Upper/ Lower"** key to call a dummy spectrum into both upper and lower display.

The dummy spectrum can be any spectrum saved in the data memory having the same Measurement Type and Filter Bandwidth as the user-defined weighting/reference spectrum.

6. Add the user-defined weighting/reference spectrum, defined in step 2, to the upper display by using **"F4"**.
7. Use **"F5"** to select "dB" calculation mode.
8. Press **"F7"** to subtract the spectra and place the result in the upper display.

The contents of the upper display are now the user-defined weighting/reference spectrum entered in step 2. This can now be saved in data memory (and from there to disk) by pressing **"Prev. Page"** to return to page 3 of the Spectrum Calculator menu and using **"F2"**.

9.2.2 Standard Weightings

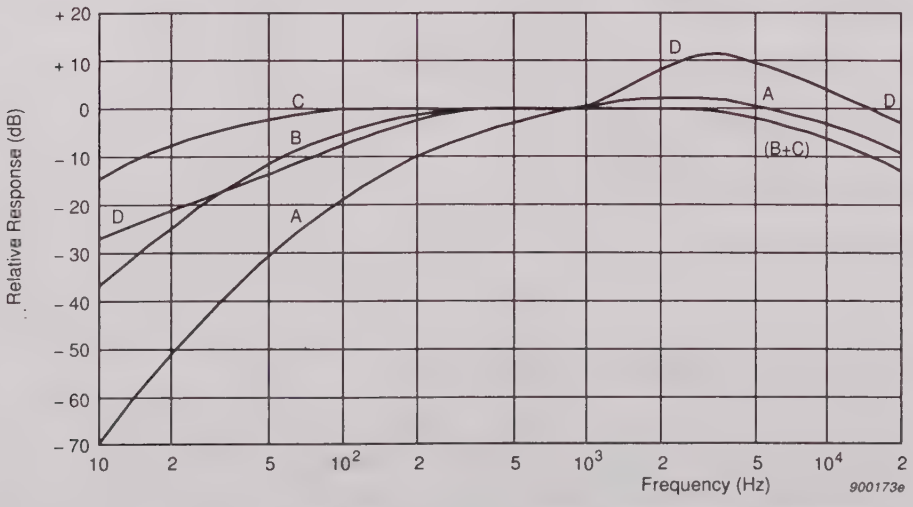

Fig. 9.1 Standard A-, B-, C-, and D-weightings

Four standard weightings can be chosen from the Weighting menu: A-, B-, C-, and D-weightings. These have weight numbers 5 to 8. Fig. 9.1 shows the four weighting curves.

9.2.3 Weight Functions Based on Measurement Data

Files stored in the data memory can be used as a basis for weighting functions. This is done by entering the file number and pressing **"F6"** on page 2 of the Spectrum Weighting menu. The bandwidth of the recalled data is automatically adjusted to the bandwidth specified in the Current Set-up.

9.3 Spectrum Unit

The Spectrum Unit is calculated in real-time and can be changed using the Display Modes menu. There is a choice of five different spectrum units:

PWR: Power = Mean Square = $\overline{x^2(t)} = \frac{1}{T}\int_0^T x^2(t)\,dt$

RMS: Root Mean Square = $\sqrt{\text{PWR}}$

ENG: Energy = $\int \text{PWR}\,dt$

ESD: Energy Spectral Density = $\frac{\text{ENG}}{\text{BW}}$

PSD: Power Spectral Density = $\frac{\text{PWR}}{\text{BW}}$

where BW is the filter bandwidth.

9.4 Integration and Differentiation

The input spectrum can be integrated or differentiated once or twice. This is a purely digital processing feature which is selectable in the Display Modes menu. Integration, for example, is used for obtaining a vibration velocity spectrum from an accelerometer measurement.

Chapter 10

Building Acoustics

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10.1 The Boom and Mux Application

The Boom and Mux Application is the "fifth analyzer" in the 2144 (the four Measurement Types being the others, see section 5.2). This application is included as standard in the 2144 software and is selected from the Applications menu on page 3 of the Main menu.

When activated, the Boom and Mux Application enables the 2144 to collect data in building acoustics measurements where it is necessary to control a sound source and measure in multiple microphone positions. Type 2144 is not capable of making calculations based on the measured data. Sound Source Type 4224 (or Sound Power Source Type 4205) is used for creating a sound field and two of these can be controlled from the analyzer. Measurements can be made either manually by placing a microphone in different positions, or can be automated by using a Brüel & Kjær Rotating Microphone Boom Type 3923 or Multiplexer Type 2811. Up to four multiplexers can be connected allowing for 32 measurement points for each channel.

The connected equipment is specified on pages 1 and 2 of the Boom/Mux menu and the measurement parameters are set up on pages 3 and 4. Basic parameters (Filter Bandwidth, Type of Input, etc.) are set via the Main menu.

Notes:

- Measurements are saved in a multispectrum. You must therefore open the file before you start measuring to save the spectra. By not opening the file first you can check whether the set-up is correct without saving any spectra.
- The filter bandwidth in the Boom and Mux Application is restricted so that only real-time analysis is selectable.
- The Averaging and Trigger Multimode menus are disabled.

Brüel & Kjær PC software WT 9343 is available for building acoustics calculations. By using this program, the 2144 can be fully controlled from a computer over the IEEE or RS–232 interface (see separate interface manual).

10.2 Building Acoustics Data Collection

10.2.1 Equipment Set-up

The first two pages of the Boom/Mux menu are used for setting up general parameters, for example for the measuring equipment:

1. Activate the application by pressing **"F1"** on page 1 of the menu.
2. On page 1 of the Boom/Mux menu, use **"F2"** to select DECAY for reverberation time data collection or SPL for sound pressure level measurements.
3. Use **"F3"** to select which sound source must be active when the measurement starts.
4. If required, Autorange can be set permanently by using **"F4"**.
5. Set the averaging time for the Autorange function using **"F5"**.
6. Set a Delay Before Measurement Start using **"F6"** if you need time to, for example, leave the room.
7. Press **"F8"** to go to page 2.
8. Use **"F2"** to select the type of equipment that the microphone is connected to.
   (a) If a microphone boom is used, select a number of measurement positions (1 to 3) using **"F4"**.
   (b) If a multiplexer (MUX) is used, first select STEP (using **"F3"**) and set Number of Positions (**"F4"**): if, for example, an 8-channel multiplexer is used and channels 2 and 3 are disabled, set the number of positions to 6. The six channels are then monitored in the sequence 1, 4, 5, 6, 7, 8. If required, a measurement can be made using a single channel (SINGLE): in the example above, setting Single Position Number to 4 will feed through the signal from channel 6.
   (c) If the microphone is connected directly to the analyzer, set Equipment Type to NONE.
9. Press **"F7"** to go to page 3 or 4, depending on whether DECAY or SPL has been selected.

10.2.2 Reverberation Time (Decay)

Reverberation time data collection requires the use of multispectra (one multispectrum for each microphone position). Page 3 of the Boom/Mux menu provides a convenient way of setting up such a multispectrum:

1. Set-up the parameters according to Fig. 10.1.

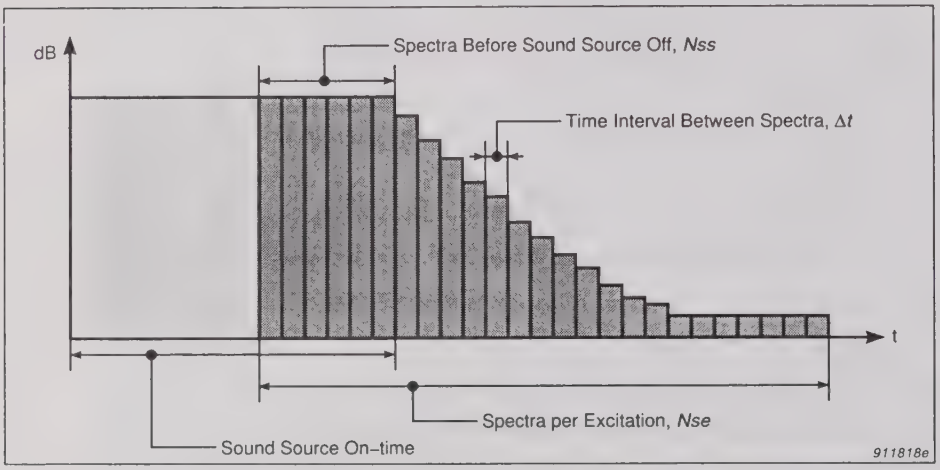

Fig. 10.1 Parameters for collection of reverberation time data in a multispectrum (one excitation shown)

Note that, since there is no Averaging menu in the Boom and Mux Application, the averaging mode is set either on page 3 of the Boom/Mux menu using **"F2"** or in Measurement Mode using the **"Lin."/"Exp."** hard keys. The averaging time, T_{avg} , is automatically set by the analyzer, based on the value of Δt, the Time Interval Between Spectra. For exponential averaging, T_{avg} is set to the nearest value $\geq \frac{2}{3}\Delta t$ and for linear averaging, $T_{avg} = \Delta t$.

2. Press **"Meas. Mode"** to go to Measurement Mode.

It is often a good idea to give special names to a group of related files. For example, all "decay" files could be given names from 101 to 199.

3. If a special file name is required, key-in the name and open the file by pressing **"F4"** on Measurement Mode page 2.
4. Press **Averaging Control "Start"** to start the data collection.

Each file in a decay measurement contains a multispectrum with one or more reverberation decays, representing a single microphone position. The number of decays per multispectrum is determined by the `Excitations per Position` field.

Estimates for RT (Reverberation Time)

As an aid for setting up the multispectrum for a reverberation time measurement, the analyzer calculates estimates for the maximum and minimum reverberation times that can be measured with the actual set-up. These are displayed in the lower left-hand corner of the screen. In order to capture the whole reverberation decay, the parameters must be set so that the expected reverberation time is within the estimated limits. The estimates are calculated the following way:

$$\text{Estimated max. RT} = (N_{se} - N_{ss})\,\Delta t\,\frac{60\,\text{dB}}{ER + 5\,\text{dB}}$$

$$\text{Estimated min. RT} = 3\,\Delta t\,\frac{60\,\text{dB}}{ER}$$

or

$$\text{Estimated min. RT} = 14\,T_{avg}\ \text{(exp. avg. only)},$$

whichever of the two is greater.

N_{se} = number of spectra per excitation
N_{ss} = number of spectra before the sound source is switched off
Δt = time interval between spectra
ER = estimation range in dB, starting 5 dB below the steady state level

If the number of spectra after the sound source is switched off $(N_{se} - N_{ss})$ is less than 4, the estimates are not calculated. Instead, `UNDEFINED` is displayed.

Note: The estimated value for min. RT does not take into account that filter ringing may influence the results at low frequencies. Gen-

erally, the restriction $B \times RT \geq 16$ determines the limit for how short reverberation times can be measured (B is the filter bandwidth in Hz). As an example, the reverberation time at 125 Hz should be more than 0.5 seconds to ensure precise results with 1/3-octave bandwidth.

Using the Estimation Range to Determine the Set-up Parameters

The estimation range should be set to the value that is going to be used during later post-processing. Usually, only 20 dB of the reverberation decay (–5 dB to –25 dB) is used for determination of the reverberation time. To optimize the set-up for this purpose:

1. Set `Estimation Range for max/min RT` to, for example, 20 dB.
2. Adjust the total number of spectra and recording speed so that the expected reverberation time of the room lies within the estimated minimum and maximum limits.
3. Make sure that the output level of the loudspeaker is sufficiently high so that the specified 20 dB range is well above the background noise.

10.2.3 Sound Pressure Level Measurements

For sound pressure level measurements, the analyzer uses linear averaging only. To make a sound pressure level measurement:

1. On page 1 of the Boom/Mux menu, select `SPL` using **"F2"**.
2. Press **"F7"** to go to page 4, `(SPL)`.
4. Set `Sound Source On-time Before Meas.` using **"F1"** to allow the source to build up a steady sound field before the measurement starts.
5. Set the measurement time (= linear averaging time) using **"F2"**.
6. If required, a delay before each step in a measurement can be entered using **"F3"**.
7. Press **"Meas. Mode"** to go to Measurement Mode.

It is often a good idea to give special names to a group of related files. For example, all "source room SPL" files could be given names from 201 to 299.

8. If a special file name is required, key-in the name and open the file by pressing **"F4"** on Measurement Mode page 2.
9. Press **Averaging Control "Start"** to start the data collection.

Each file in an SPL measurement contains a multispectrum with one or more spectra. The number of spectra per multispectrum is equal to the number of measurement positions.

2-channel SPL Measurements

The 2144 controls two sound sources and two booms/multiplexers. Airborne sound transmission, for example, can therefore be measured easily by placing the source in one room and measuring the SPL simultaneously in the source and receiving rooms:

1. Go to the Measurement Type menu and select `2-channel Autospectrum Analysis` by pressing **"F2"**.
2. Follow the instructions above.

Each file contains a multispectrum. The number of composite spectra (see section 5.3) per multispectrum is equal to the number of measurement positions. If the sound source was connected to the A-channel during the measurement, then the source room SPL is in Autospectrum A (`Auto-A`) and the receiving room SPL is in `Auto-B`.

10.2.4 Disabling the Boom and Mux Application

To disable the Boom and Mux Application, go to page 1 of the Boom/Mux menu and press **"F1"** to position the field selector over `INACTIVE`.

All settings in the Boom/Mux menu are saved internally when the application is disabled. The analyzer is returned to "normal" 2144 mode with the Averaging and Trigger Multimode menus active again and with all settings as they were before the Boom and Mux Application was activated.

Chapter 11

Specifications

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11.2 Filter Characteristics 11–7

11.1 Main Specifications

Input Characteristics

All inputs pseudo difference. Choice of analogue ground floating or connected to chassis. Individual set-up for each channel

PREAMPLIFIER INPUT:
Pseudo Difference Input: Two standard Brüel & Kjær 7-pin Preamplifier sockets or one 18-pin LEMO socket (for sound intensity probes)
Input Impedance (Signal to Signal Ground): 1 MΩ ‖ 100 pF
Signal Ground to Analogue Ground Impedance: 50 Ω ‖ 10 nF
Frequency Range: 0.7 Hz to 25 kHz, ± 0.1 dB
Noise Floor: 1 μV, measured in 1/3-octave bands
Max. Input Voltage: 15 V peak
Attenuator: FSD from 10 mV to 3.16 V (RMS sine) in steps of 5 dB
Microphone Polarization: 0 V, 28 V, 200 V from 10 MΩ source
Power Supply: 28 V
Heater Voltage: None
High-pass Filter Cut-offs:
−0.1 dB at 0.7 Hz (6 dB/octave)
−0.1 dB at 20 Hz (12 dB/octave)
−0.1 dB at 100 Hz (12 dB/octave)
A-filter: According to IEC publication 651 type 0

DIRECT INPUT:
Pseudo Difference Input: Two BNC sockets (via preamplifier-to-BNC adaptors)
Input Impedance (Signal to Signal Ground): 1 MΩ ‖ 100 pF
Signal Ground to Analogue Ground Impedance: 50 Ω ‖ 10 nF
Frequency Range: 0.7 Hz to 25 kHz, ± 0.1 dB
Noise Floor: 1 μV, measured in 1/3-octave bands
Max. Input Voltage: 15 V peak
Attenuator: FSD from 10 mV to 3.16 V (RMS sine) in steps of 5 dB
High-pass Filter Cut-offs:
−0.1 dB at 0.7 Hz (6 dB/octave)
−0.1 dB at 20 Hz (12 dB/octave)
−0.1 dB at 100 Hz (12 dB/octave)
A-filter: According to IEC publication 651 type 0

ACCELEROMETER INPUT:
Pseudo Difference Input: Two micro connectors, 10–32 UNF
Input Impedance (Signal to Signal Ground): 39 Ω ‖ 220 pF
Signal Ground to Analogue Ground Impedance: 50 Ω ‖ 10 nF
Frequency Range: 0.3 Hz to 25 kHz, ± 0.1 dB
Noise Floor: 10 fC, measured in 1/3-octave bands
Max. Input Charge: 15 nC peak
Attenuator: FSD from 100 pC to 10 nC (RMS sine) in steps of 5 dB
Low-pass Filter Cut-off:
−0.1 dB at 1 kHz (18 dB/octave)
High-pass Filter Cut-offs:
−0.1 dB at 0.3 Hz (6 dB/octave)
−0.1 dB at 20 Hz (12 dB/octave)
−0.1 dB at 100 Hz (12 dB/octave)

CHANNEL–TO–CHANNEL MATCH:
Max. Gain Difference: 0.1 dB from lower frequency limit f_L or DC to upper frequency limit f_U
Max. Phase Difference:

50 to 250 Hz	< 0.017 deg.
315 to 630 Hz	< 0.042 deg.
630 Hz to 1.25 kHz	< 0.083 deg.
1.25 to 2.5 kHz	< 0.166 deg.
2.5 to 5 kHz	< 0.333 deg.
5 to 15 kHz	< 0.666 deg.

MAXIMUM VOLTAGE RATINGS:
Input: 15 V peak, 50 V DC for direct and preamplifier inputs
Signal Ground/Chassis Ground: Type 2144 is a safety class II instrument (IEC 348). For safe operation in accordance with IEC 348, the voltage between signal ground and chassis ground (in "floating" mode) must not exceed 42 V RMS. To ensure safe operation in accordance with IEC 348 at higher voltages, the user must limit all input currents to 0.7 mA peak
Signal Ground/Analogue Ground: 5 V peak. If this limit is exceeded, the user must limit the ground current to 50 mA. If the voltage exceeds 1 V peak, the dynamic range is decreased

MAXIMUM INDUCED COMMON MODE VOLTAGE:
42 V RMS, 100 V peak

COMMON MODE REJECTION:
Floating input, 50 Ω source impedance:
DC to 1 kHz > 80 dB
1 kHz to 25 kHz > 60 dB

DIFFERENTIAL COMMON MODE REJECTION:
50 Ω source impedance: > 35 dB

OVERLOAD DETECTION:
Analogue and A/D-converter overloads indicated.

CROSSTALK:
–60 dB

ATTENUATOR LINEARITY:
± 0.1 dB

ANTIALIASING FILTER:
Cut-off Frequency: 25.6 kHz (single channel), 12.8 kHz (dual channel). Provides at least 80 dB attenuation of those input frequencies which can cause aliasing

SAMPLING:
Rate: 1 × 65536 Hz or 2 × 32768 Hz

A/D-CONVERSION:
Resolution: 16 bit
Quantizing Error: Maximum 1/2 LSB

Digital Filters

1/1-OCTAVE FILTERS:
14-pole filters with centre frequencies given by $10^{3 \times n/10}$. Fulfil IEC 225-1966, DIN 45651 and ANSI S1.11-1986, Order 7 Type 1-D, optional range
Single Channel: –1≤n≤14. 16 filters with centre frequencies from 0.5 Hz to 16 kHz
Dual Channel: –1≤n≤13. 15 filters with centre frequencies from 0.5 Hz to 8 kHz

1/3-OCTAVE FILTERS:
6-pole filters with centre frequencies given by $10^{n/10}$. Fulfil IEC 225-1966, DIN 45651 and ANSI S1.11-1986, Order 3 Type 1-D
Single Channel: –4≤n≤43. 48 filters with centre frequencies from 0.4Hz to 20 kHz
Dual Channel: –4≤n≤40. 45 filters with centre frequencies from 0.4Hz to 10 kHz

1/12-OCTAVE FILTERS:
6-pole filters with centre frequencies given by $10^{(n + 0.5)/40}$
Single Channel: –18≤n≤173. All 192 filters with centre frequencies from 0.365 Hz to 21.752 kHz can be measured in a four-pass mode, or 168 filters from 0.365 kHz to 5.464 kHz can be shown in real-time
Dual Channel: –18≤n≤161. All 180 filters with centre frequencies from 0.365 Hz to 10.902 kHz can be measured in a four-pass mode, or 156 filters from 0.365 kHz to 2.738 kHz can be shown in real-time

1/24-OCTAVE FILTERS:
6-pole filters with centre frequencies given by $10^{(n + 0.5)/80}$
Single Channel: –36≤n≤347. All 384 filters with centre frequencies from 0.360 Hz to 22.067 kHz can be measured in an eight-pass mode, or 312 filters from 0.360 Hz to 2.778 kHz can be shown in real-time
Dual Channel: –36≤n≤323. All 342 filters with centre frequencies from 0.360 Hz to 11.060 kHz can be measured in an eight-pass mode, or 288 filters from 0.360 Hz to 1.392 kHz can be shown in real-time

System Accuracy

DYNAMIC RANGE:
All distortion (intermodulation and harmonic) and spurious noise at least 80 dB below max. input voltage for 1/3-octave autospectrum

OVERALL FREQUENCY RESPONSE:
± 0.1 dB at filter centres from lower frequency limit (0.3 Hz) to upper frequency limit (22.4 kHz)

NOISE:
Voltage Input: < 1 μV from 0.7 Hz to 20 kHz, measured in 1/3-octave bands in input range 10 mV with input short-circuited

Charge Input: < 10 fC from 0.3 Hz to 20 kHz, measured in 1/3-octave bands in input range 100 pC with 1 nF transducer capacitance

AMPLITUDE MEASUREMENT STABILITY:
± 0.1 dB

AMPLITUDE LINEARITY:
± 0.05 dB or ± 0.005% of maximum input voltage, whichever is greater, measured using a sine wave input at the filter centre frequency. With measurements more than 40 dB below max. input voltage, the measuring sine wave is accompanied by another sine wave of a lower frequency outside the measured band, having an amplitude greater than 20 dB below max. input voltage

FREQUENCY ACCURACY AND STABILITY:
0.01% without warm-up (no adjustment necessary)

Detectors

Digital true RMS detection of filter bank and two broadband channels. No crest factor limitation

CONTROL:
Start: Clears the average accumulator and starts an average
Stop: Stops the averaging process

Proceed: Continues an average without clearing the average accumulator
Averaging Gate: External or internal trigger signal for gating of the averaging process

LINEAR:
Averaging without truncation.
Single Channel: Averaging times from 1 ms to 24 hours selectable to a resolution of 1 ms in the range 1 ms to 1 hr and to 1 s in the range 1 hr to 24 hours
Dual Channel: Averaging times from 2 ms to 24 hours selectable to a resolution of 2 ms in the range 2 ms to 1 hr and to 1 s in the range 1 hr to 24 hours

EXPONENTIAL:
Single Channel: 19 averaging times from 1/512 s to 512 s in a binary sequence
Dual Channel: 18 averaging times from 1/256 s to 512 s in a binary sequence
Averaging times of 1/4 s and 2 s correspond to "Fast" and "Slow" sound level meter responses, respectively

Data Memory

Non-volatile internal memory for 111 single spectrum or multispectrum files each labelled with up to 40 characters of user-defined text. The text label is stored together with data and is shown in the file list

Control: Manual save or multispectrum automatic save
Start Conditions: Free Run, Manual, External, Absolute Time, or Internal triggering at a specified level with selectable slope
Delay: Pre- and post-trigger delay between start condition and actual multispectrum start, set in seconds
Multispectrum Update Rate: From 1 ms (2 ms for dual channel) to 24 hours, with 1 ms resolution
Max. No. of Spectra: 2457 (for single channel 1/1-octave autospectra)
Max. (or Min.) Hold, All Bands: Composite spectrum of max. (or min.) RMS level occurring in each channel
Max. (or Min.) Hold, Specified Band: Retains the spectrum for which max. (or min.) RMS level has occurred in the specified band

Mass Storage

Built-In disk-drive for storage of measured data and optional programs
Data Media: Removable 3½″ double sided, high density or double density micro floppy disk
Data Format: Compatible with PC/MS-DOS from version 3.2. PC-DOS is a trademark of International Business Machines Corporation. MS-DOS is a trademark of Microsoft Corporation
Formatted Capacity: 1.44 Mbytes (HD) or 720 kbytes (DD)
File List: Contains disk identification, user-definable volume label and file list sorting key. Each file is identified by user-definable file number, data type, size and start time of the measurement

Hard Copy

Graphics Printer: Any display on Type 2144, including graphics and all notation, can be printed on graphics printers with IBM, HP or Epson print formats or on Brüel & Kjær Graphics Recorder Type 2313

Autosequence

Allows the user to specify an autosequence of front panel keypushes, the functions of which can be executed on command. Maximum 200 key entries per autosequence. Up to 4 autosequences can be saved in non-volatile memory

Display

Liquid Crystal Display (dot matrix, super twisted nematic) with back-light and resolution 480 × 200 points

DISPLAY FORMATS:
Single: A single spectrum showing pressure, acceleration, intensity, particle velocity, phase, and coherence. Digital integration or differentiation of spectrum is possible
Dual: Two spectra (two input spectra or input spectrum and recalled spectrum) displayed in upper and lower parts of the display, respectively
Difference: Two spectra. The upper is the difference and the lower is the recalled
Slice: A time slice through a multispectrum
Menu: The text shown relates to the soft key control

Y-AXIS:
Annotation: Absolute units or relative units (dB). Selectable dB reference

Calibration: Pressure, acceleration. Verification of particle velocity, active and reactive intensity. Measurement of pressure–residual intensity index. Direct entry of transducer sensitivity or autocalibration with an appropriate calibrator. Direct entry of dB reference
Spectrum Type: RMS, power, power spectral density, energy spectral density or energy
Amplitude Scroll: Hard key controls to shift the display up and down.

X-AXIS:
Spectrum Display: Logarithmic axis with annotation in Hz at 1/1-octave centre frequencies conforming with ISO R266. Range from 1 to 16 octaves. 11 octaves at a time can be shown on the display
Frequency Scroll: Hard key controls to shift the display left and right
Slice Display: Linear axis annotated from with index numbers from 1 up to a maximum of 999 (representing time, points, etc.)

CURSOR:
Reads frequency in Hz on the x-axis (spectrum display) or index number (slice display) and at the same time reads amplitude level in dB or absolute units and phase in degrees on the y-axis

Operation

Menus: User-interactive menus are used to set-up the analyzer for measurements. 4 user-defined measurement set-ups can be saved and recalled from non-volatile internal memory
Measurement Mode: For enabling measurements
Data View: For looking at spectra and slices in the internal non-volatile memory
Help Pages: Each user-interactive menu is provided with a corresponding page of help text

IEEE/IEC Interface

Conforms to IEEE 488.1 and IEC 625-1 standards. Any function shown on display (including measured data, post-processed result, measurement set-up, display set-up or calibration set-up) can be transmitted to and from the analyzer

FUNCTIONS IMPLEMENTED:

Source Handshake	SH1
Acceptor Handshake	AH1
Talker	T5
Listener	L3
Service Request	SR1
Remote/Local	RL1
Parallel Poll	PP1
Device Clear	DC1
Device Trigger	DT1

COMMAND SET:
Simple and easy to remember standard engineering English. Resistant to operator error

CODE:
ASCII (ISO 7-bit) code, or binary

INTERFACE TERMINATOR:
Can be specified on the Interface Menu

DEVICE ADDRESS:
Can be specified on the Interface menu

RS–232–C Interface

Conforms with the EIA Standard RS–232–C (equivalent to CCITT V24). Allows remote activation of the front panel key functions via a non-intelligent terminal, either directly or via a modem

Input/Output

Trigger Input: BNC connector for external trigger to start an average instantaneously or with user-defined delay
Remote Control: Two 8-pin DIN sockets for remote control of Rotating Microphone Boom Type 3923 or Multiplexer Type 2811. Two 8-pin DIN sockets for remote control of Sound Source Type 4224. 18-pin LEMO socket for connection of Intensity Probe Type 3548 including Remote Control Handle ZB 0017

Power Supply

Battery: 6 rechargeable NiCd cells (QB 0008) operate the system for $>$ 4 hrs continuous use at 25°C ($>$ 6 hrs with alkaline batteries). The operating time is reduced if disk-drive or interface bus is used and decreases with decreasing temperature.
Mains: An external source or filtered DC power in the range of 11–16 V DC will power the analyzer continuously. The Brüel & Kjær Power Supply ZG 0199 fits into the slot normally occupied by the battery pack
Power Consumption: 900 mA during measurements at a typical battery drive-voltage of 7.5 V (back lighting off)

Environmental

OPERATING TEMPERATURE:
Analyzer: −10°C to +55°C (+14°F to +131°F)
Disk-drive: +5°C to +50°C (+41°F to +122°F)

STORAGE TEMPERATURE:
−25°C to +70°C (−13°F to +158°F)

HUMIDITY:
90% RH (non-condensing at 40°C)(+104°F)

ELECTROMAGNETIC COMPATIBILITY:
Complies with requirements for class B computing device of the American FCC Rules

Cabinet

DIMENSIONS:
Height: 175 mm (6.89″)
Width: 356 mm (14.02″)
Depth: 293.5 mm (11.56″)
Weight: 9.3 kg (20.46 lb)

Accessories Included

Power Supply	ZG 0199
7-core DIN Cable (1.5 m)	AQ 0035
Battery Box	ZG 0146
6 × 1.25 V NiCd Batteries, type R 20 ("D" size)	QB 0008
3-pin Plug	JP 0312
8-pin DIN Plug	JP 0808
2 × 5 A Fuses	VF 0087
Shoulder Strap	DH 0541
Charging Adaptor	AQ 0157
2 × Preamp-to-BNC Adaptors	JP 0736
2 system software disks VP 7278	BZ 5048

Accessories Available

TRANSDUCERS:

Sound Intensity Probe	**Type 3548**
General-purpose ½″ Measuring Microphone	**Type 4165**
Microphone Preamplifier	**Type 2639**
General-purpose Accelerometer	**Type 4371**

Brüel & Kjær supplies a wide range of microphones and accelerometers. Please ask for more information regarding the different types and their uses.

CALIBRATION:

Sound Intensity Calibrator	**Type 3541**
Multifunction Acoustic Calibrator	**Type 4226**
Pistonphone	**Type 4228**
Sound Level Calibrator	**Type 4230**
Calibration Exciter	**Type 4294**

BUILDING ACOUSTICS:

Eight Channel Multiplexer	**Type 2811**
Rotating Microphone Boom	**Type 3923**
Sound Source	**Type 4224**

APPLICATION PROGRAMS:

Dual Channel FFT Option for Type 2144	**Type 7651**

COMPUTER SOFTWARE:

Sound Intensity Program	WT 9378

INTERFACE:

Adaptor to convert IEEE 488 connector to IEC 625-1 (25-way)	AO 0195
Interface Cable (2 m), IEC 625-1 (25-way) to IEEE 488	AO 0264
Interface Cable (2 m), IEEE 488	AO 0265
IEEE 24-way bus connector kit	UA 0814

MISCELLANEOUS:

1.25 V NiCd Battery, type R 20 ("D" size)	QB 0008
10 3.5″ Floppy Disks (1 MB)	QR 1102
10 3.5″ Floppy Disks (2 MB)	QR 1105

11.2 Filter Characteristics

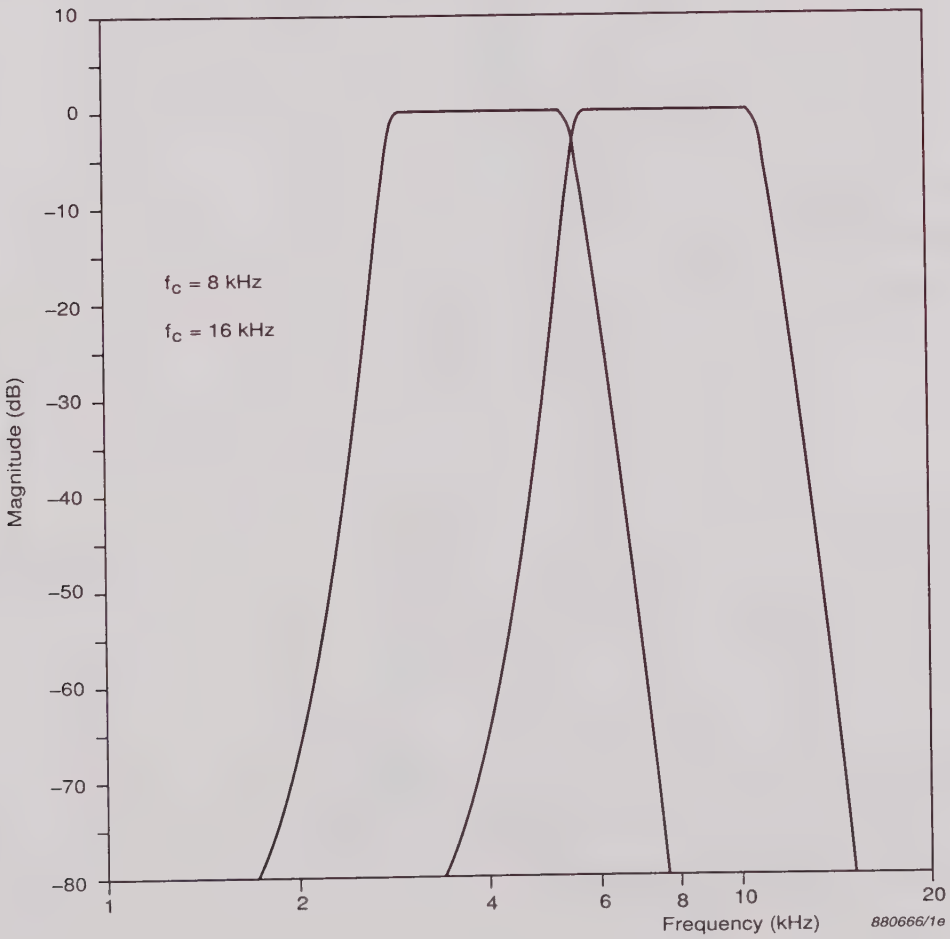

Fig. 11.1 1/1-octave filter characteristics

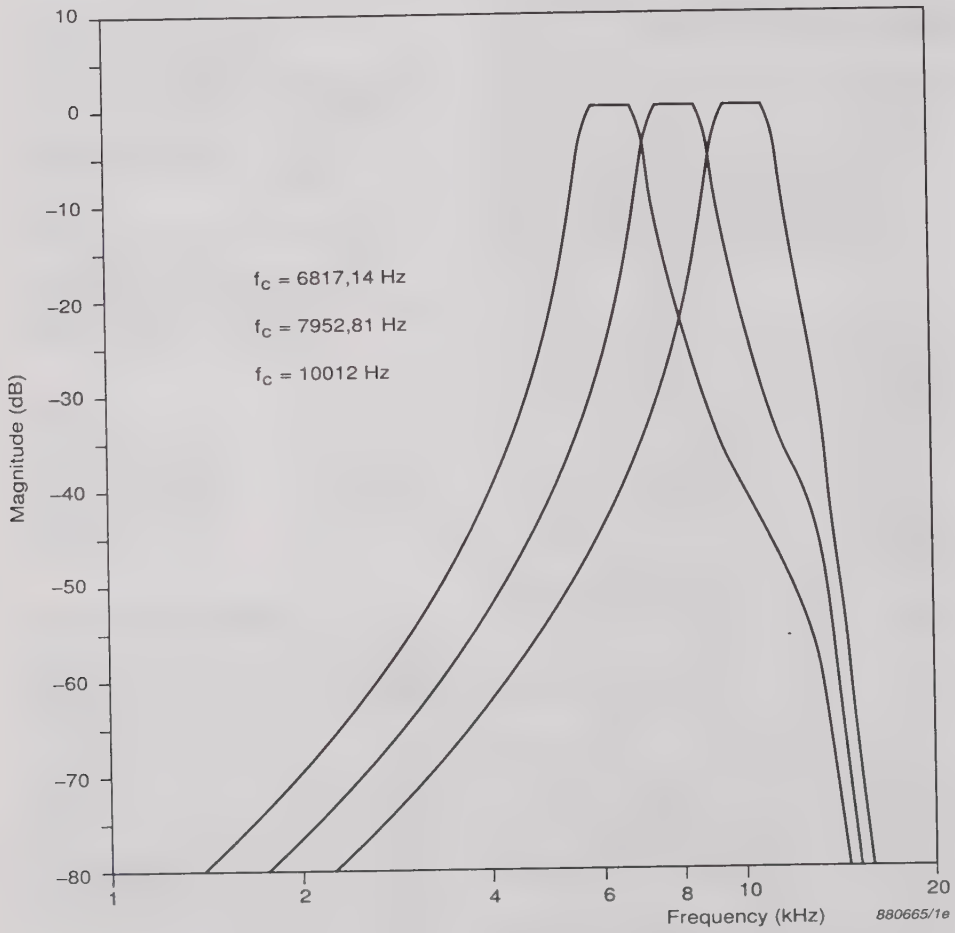

Fig. 11.2 1/3-octave filter characteristics

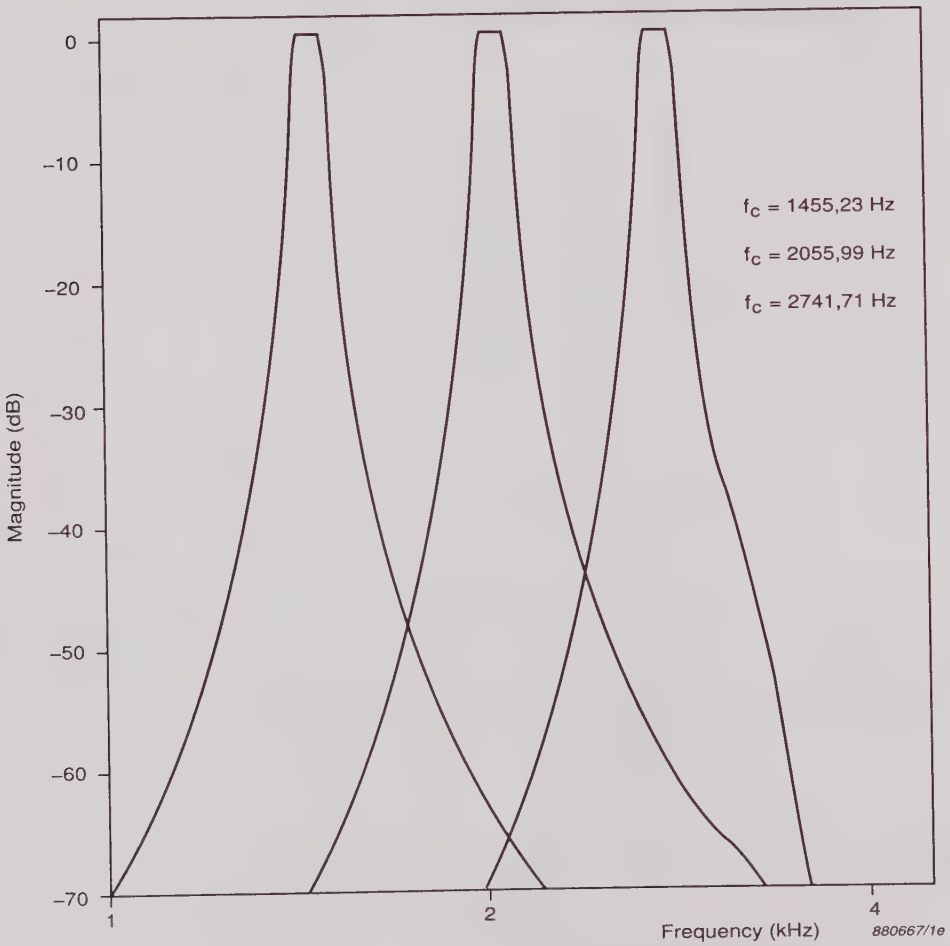

Fig. 11.3 1/12-octave filter characteristics

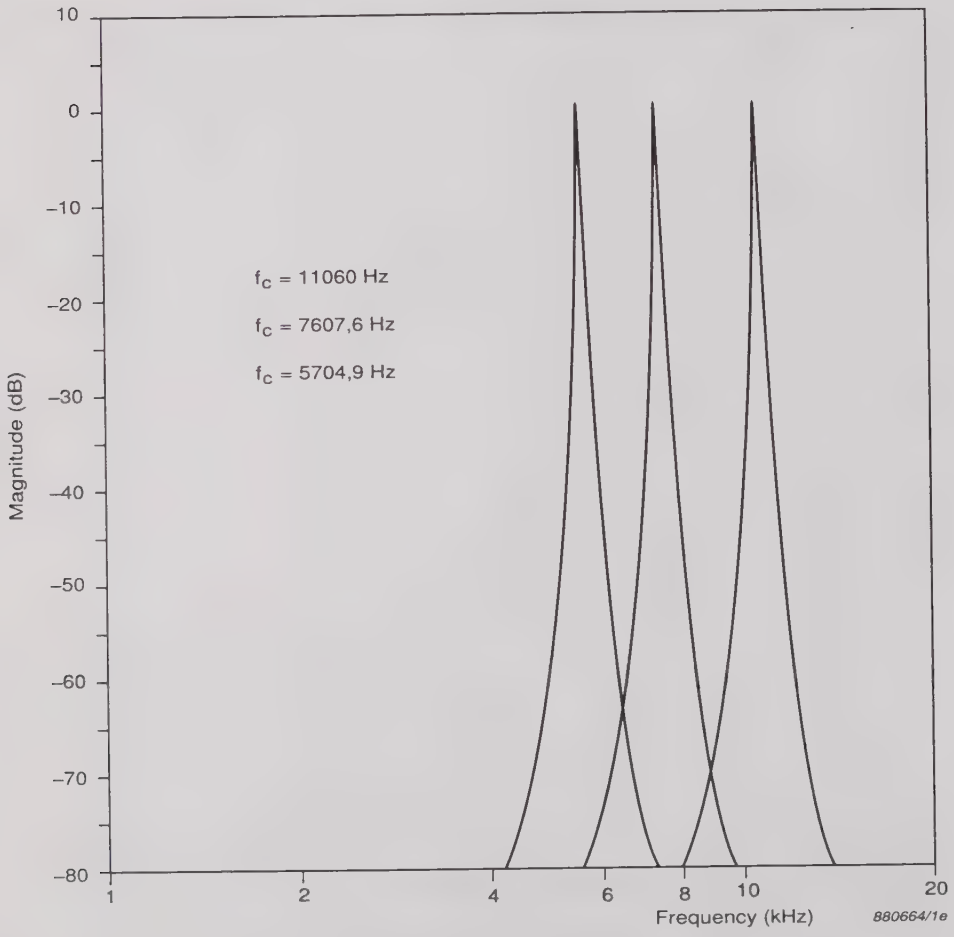

Fig. 11.4 1/24-octave filter characteristics

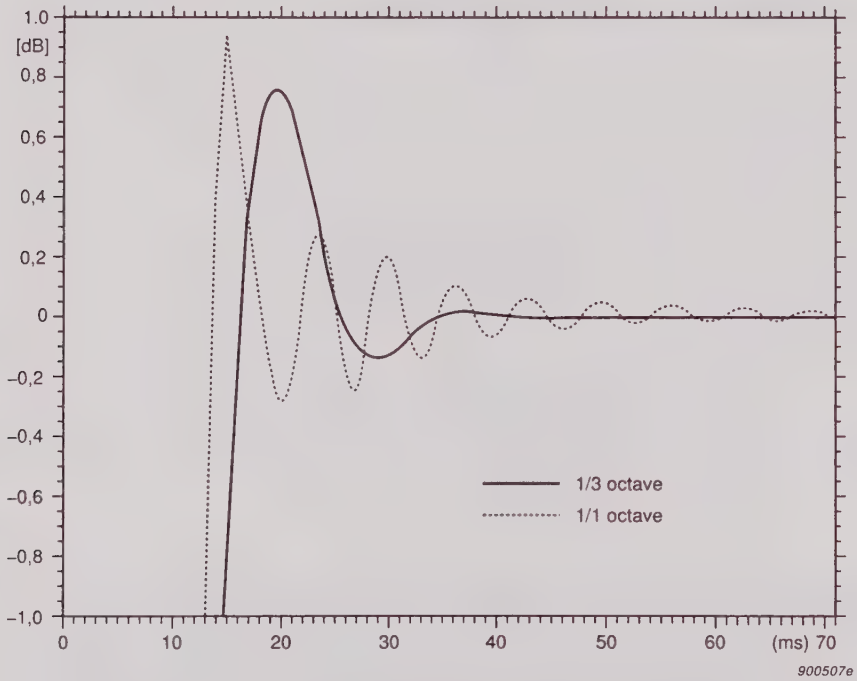

Fig. 11.5 Total filter response time for 1/1- and 1/3-octave filters at 512 Hz

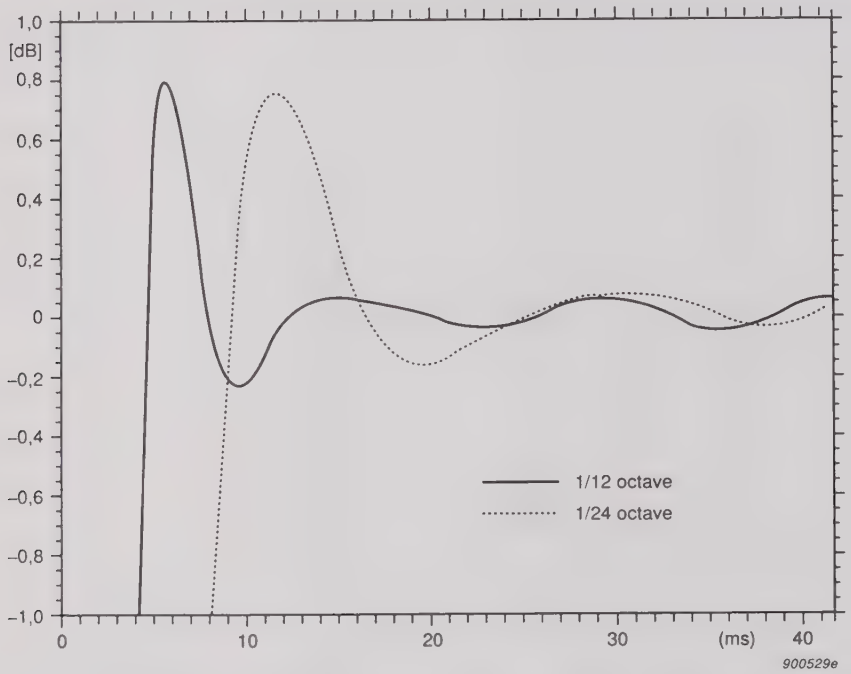

Fig. 11.6 Total filter response time for 1/12-octave filter at 516 Hz and 1/24-octave filter at 508 Hz

Chapter 12

Service and Repair

Dual Channel Real-time Frequency Analyzer Type 2144 is designed and constructed to provide you with many years of reliable operation. However, if a fault occurs which impairs its correct function, then remove the battery pack and/or disconnect the power supply to prevent risk of further damage. For repair, contact your local Brüel & Kjær service representative. Under no circumstances should repair be attempted by persons not qualified in the service of electronic instrumentation.

Chapter 13

Appendix

13.1 Error Messages 13–2

Errors in the Power-on Self Test 13–2
Errors in the Program Retention Test 13–2
Errors in the Internal Memory 13–3
Run-time Errors 13–3
Provoked Errors 13–5

13.1 Error Messages

When reporting an error to your Brüel & Kjær service office, it is important that you always state:

1. The type of error as written on the display
2. The VP-number and program version numbers as written on the display
3. The serial number of your analyzer (stated on the rear panel)

13.1.1 Errors in the Power-on Self Test

The power-on self test looks for errors in parts of the hardware in the analyzer. In some cases it is possible to use the analyzer even though a self test error has been detected, and the message `Press <Main Menu> to continue` is displayed. All saved files will, however, be marked `HWF` (hardware failure) to indicate that data may not be reliable. Please report the error to your local Brüel & Kjær office.

13.1.2 Errors in the Program Retention Test

This type of error is usually not fatal. If the analyzer is not used for a long time, the back-up battery may lose its power and the memory, including the program, is lost. A typical error message is:

```
Retention test completed with ERROR status!

err 9304 : Main program not valid
Ready for program load
```

If there is no disk in the disk drive, the message `err 9106 : No disk` is displayed. When you insert the program disk or if the disk is already in the disk drive, the analyzer automatically starts reading the disk, displaying the message `Loading program from floppy disk`.

13.1.3 Errors in the Internal Memory

After the retention test the main program looks for errors in the internal memory. Fig. 13.1 shows a list of possible errors:

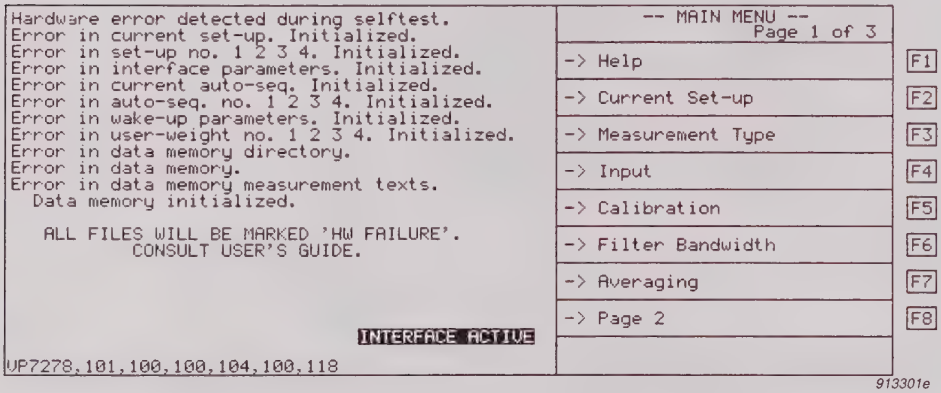

Fig. 13.1 Display showing a list of possible memory errors

The error messages can usually be removed by pressing **"Reset"** or by making a Master Reset (see section 4.1). It is, of course, important to understand that removing the *symptom* of the error does not remove the error itself. If, for example, part of the memory directory is overwritten, this is initialized by the analyzer. All files in the data memory are lost but the analyzer apparently works normally again after a reset. However, what *caused* the overwriting was probably a hardware error and it may cause problems again if it is not removed. If an error turns up repeatedly, please report it to your local Brüel & Kjær office.

Note: `Last usage terminated by power failure` is not an error message as such but a warning to tell you that the analyzer was not switched off using the **"Power On/Off"** key. Press the **"Reset"** key to remove the warning.

13.1.4 Run-time Errors

If a run-time error occurs and causes an internal stop, a screen pic-

ture such as that shown in Fig. 13.2 appears on the display. Usually, saved files remain intact.

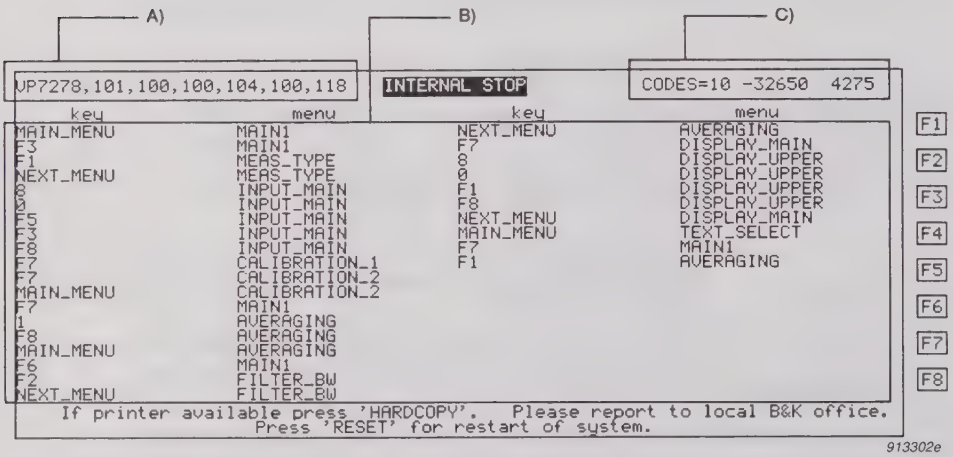

Fig. 13.2 Example of screen picture which appears if a run-time error occurs

The information on the screen is divided into three groups named A, B, and C on the figure:

A) VP is the program version number

B) CODES tells the service engineer what type of error caused the run-time error and where it occured in the program

C) The latest key-pushes are shown so that, if necessary, it is possible to provoke the error again

When reporting a run-time error to a Brüel & Kjær office, it is important that you give *all* the above information to the service personel; this saves time for both you and the service engineer. The easiest way to document the error is to print the screen picture out on a printer by pressing **"Hard Copy"**. This requires that the printer is already connected and that the interface parameters are set correctly. The interface is automatically activated if a run-time error occurs. If no printer is available, write down at least the VP-number, the codes, and the last 5 key-pushes.

13.1.5 Provoked Errors

When using the analyzer, you might sometimes provoke errors, for example by making an illegal choice. This results in a message from the analyzer appearing in the lower right-hand corner of the screen. Many of these messages are just to tell you that you have made a mistake and are often self explanatory. The list below shows some serious faults which might not be immediately understandable:

ACCUM. OVERFLOW
Cause: Numeric overflow when the attenuation is changed.
Action: Data unreliable. Make a new measurement.

ACCUM. UNDERFLOW
Cause: Numeric underflow when the attenuation is changed.
Action: Data unreliable. Make a new measurement.

BAD DIRECTORY
Cause: Logical error in the disk directory preventing write access to the disk.
Action: Transfer whatever possible and format the disk.

BAD DISK
Cause: Logical (CRC) error on the disk.
Action: Transfer whatever possible and format the disk.

BATTERY
Cause: Batteries cannot supply enough current to the 2144.
Action: Change or recharge the batteries.

BOOM TIMEOUT
Cause: Expected feedback from boom has not been received within 68 sec.
Action: Check the boom batteries or the set-up.

COMMON OVERLOAD
Cause: See section 5.1.3.
Action: Reduce the common mode input voltage.

CRC FAULT
Cause: A logical error was detected during a data transfer.
Action: Transfer whatever possible and format the disk.

DATA SPLIT ERR
Cause: Data is split when a long file is copied from the floppy disk.
Action: Initialize the Data Memory and try copying again. If the error occurs again, contact your local Brüel & Kjær service representative.

DISK ERR
Cause: Physical error on the disk.
Action: Transfer whatever possible and throw the disk away.

DISK-JOB ERR
Cause: Main Program error.
Action: Contact your local Brüel & Kjær service representative.

DISK USE LOCKED
Cause: Software key does not permit use of floppy drive.
Action: Contact your local Brüel & Kjær service representative.

HARDCOPY FAULT
Cause: Error during print out of the screen. The screen picture cannot be transferred from the display processor.
Action: Contact your local Brüel & Kjær service representative.

ILL. MEAS TYPE
Cause: Software key does not allow the selected measurement type.
Action: If you need to make that type of measurement, you must buy a software key. Contact your local Brüel & Kjær service representative.

MEMORY ERR
Cause: Error in Data Memory. Could have many reasons.
Action: Copy as much as you can from the Data Memory and initialize it.

NO ANALOGUE MODULE
Cause: Analogue module or software key missing.
Action: Insert the analogue module. If you need a software key, contact your local Brüel & Kjær service representative.

NO KEY
Cause: Software key is required for the measurement.
Action: Contact your local Brüel & Kjær service representative.

RECORD LENGTH ERR
Cause: Data is split when a long file is copied to the floppy disk.
Action: Press **"Reset"** and try copying again. If the error occurs again, contact your local Brüel & Kjær service representative.

TIMEOUT
Cause: Communication fault between main processor and signal processor.
Action: Press **"Reset"** or make a Master Reset. Contact your local Brüel & Kjær service representative.

PROTECT
Cause: Severe input overload. Input is protected by a short circuit.
Action: Remove the protection by pressing **"Reset"** or **"F6"** in the Input menu.

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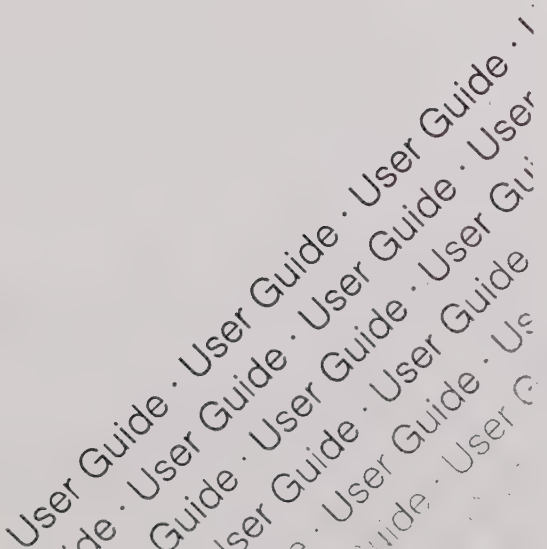
Local representatives and service organisations world-wide

Technical Documentation

Dual Channel Real-time Frequency Analyzer Type 2144

Addendum


User Guide · User Guide · User Guide ·

User Guide

Dual Channel Real-time Frequency Analyzer Type 2144

From serial no. 1 614 490

September 1992

Brüel & Kjær

BB 0880–11

Safety Considerations

This apparatus has been designed and tested according to IEC Publication 348, *Safety Requirements for Electronic Measuring Apparatus*, and has been supplied in safe condition. The present User Guide contains information and warnings which should be followed by the user to ensure safe operation and to retain the apparatus in safe condition. Special note should be made of the following:

Powering the Apparatus

Before each use of the Power Supply ZG 0199 with the apparatus, check that it is set to match the available mains voltage and that the correct fuse is installed.

Safety Symbols

⚠ The apparatus will be marked with this symbol when it is important that the user refers to the associated warning statements given in the User Guide.

⊥ Chassis terminal ⏚ Safety earth terminal ↯ Hazardous voltage

Warnings

- Switch off all equipment before connecting or disconnecting their digital interface. Failure to do so could damage the equipment.
- Whenever it is likely that the correct function or operating safety of the apparatus has been impaired, the apparatus must be made inoperative and be secured against unintended operation.
- Any adjustment maintenance and repair of the open apparatus under voltage must be avoided as far as possible and, if unavoidable, must be carried out only by trained service personnel.

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Chapter 1

Introduction

This guide is an addendum to 2144 User Guides, Vol.1 Operation (BB 0768–11) and Vol.2 Interface (BB 0783–11). It applies to software VP 7342 and describes the changes from the earlier version, VP 7303.

Chapter 2 gives details of changes in the operational features of the real-time frequency analyzer. This chapter is intended as a supplement to Volume 1 of the User Guide.

Chapter 3 concerns the use of the interface of Type 2144. In this chapter, the page numbers are not consecutive. The page and section numbers from Volume 2 have been retained so that the pages in this chapter can be used to replace the earlier version.

Chapter 2

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2.1 The Input Menu

When Type 2144 is used in single-channel mode, it is now pos sible to select whether you want to use channel A or channel 1 as the input channel. Select the required channel by pressing **"F1"**.

2.2 Spectrum Weighting Menu

It is now possible to select independent weightings for autospectra A and B:

1. Go to page 1 of the Spectrum Weighting menu.
2. Press **"F3"** to select a weighting and **"F4"** to switch inversion on or off.
3. Press **"F5"** to select the autospectrum to which the weighting will be applied.
4. If you want to add the weighting to the spectrum, pres: **"F6".**
5. If you want to add the weighting to the W-channel, press **"F7"**.
6. Repeat the procedure for the other autospectrum.

2.3 Hold Menu

The Hold menu of Type 2144 has been changed to include the popular Data Exclude feature from Type 2143. If Data Exclude has been activated in the Hold menu and an unwanted event occurs during a measurement, for example a door slamming, this part of the data can be deleted by pressing **"F3"** on page 2 of the Measurement Mode menu.

Pressing Data Exclude will delete the last 5 seconds of measure(data. The key can be pressed a maximum of 4 times (consecutively) to delete up to 20 seconds of data.

2.4 Measurement Mode

To implement the improvements detailed in sections 2.1 to 2.3, it has been necessary to make minor changes in the Measurement Mode menus. For example, the `Status` field has been moved to the top of the screen. These changes will rapidly become familiar and require no further explanation here.

2.5 Boom/Mux Menu

In the old version of the 2144, only `BOOM` could be activated. In the new version of the software, selection of `BOOM` then allows you to select which connector(s) you wish to use – `A`, `B` or `A&B`.

In addition, the Trigger Multimode and Averaging menus are disabled when Boom/Mux is active as the relevant parameters are set up on pages 3 and 4 of the Boom/Mux Menu. The parameters set up in the Trigger and Averaging menus are overwritten when Boom/Mux is activated.

2.6 Data View Menu

Type 2144 now allows three choices of x-axis: `FREQ`, `INDEX` and `OVL`. `OVL` displays an overload slice.

2.6.1 Overload Slice

When you have measured and saved a multispectrum, and recall the file for display in the Data View menu, you can use **"F2"** to toggle the x-axis to display an overload slice, OVL. For each of the individual measurements in the multispectrum, the slice displays the percentage overload during that measurement.

"F3" and **"F4"** are used to select whether the overload is to be displayed for channel A or channel B. **"F5"** and **"F6"** are used to select the index of a particular spectrum in the multispectrum.

The Y-value for that index, expressed as a percentage, can then be read from the box between F4 and F5.

Note: If you have measured, for example, a 4×4×1 matrix multispectrum, the indices of the slice will range from 1 to 16 and will always be in the same order as which you measured the multispectrum. It is therefore important to remember whether you have measured row, column, direction; column, row, direction; etc.

2.6.2 Index

If you select an INDEX display, a slice is taken through a multispectrum at the frequency you have chosen. This shows the level at that frequency for all the measurements in the multispectrum. The index number corresponds to the order in which measurements were made.

Matrix Multispectra

For matrix multispectra, the measurement an index refers to is indicated by a display of the row, column and direction numbe of the cursor-selected index.

Normal Multispectra

If you select Normal multispectra with Trigger Mode set to ACTIVE and Number of Triggers equal to 1, then there are two ways of displaying the index: INX-# and INX-TIME. INX-# is the same as INDEX above. INX-TIME shows the same slice, but the x-axis is now marked in units of time.

2.7 Master Reset

In order to make it easier to load new software into the 2144, certain changes have been made in the way a Master Reset functions. Master resetting Type 2144 now leaves the following parameters unchanged:

I/O Interface Menu

All parameters

Input Menu

- Channel
- Input
- Filter
- Low-pass 1 kHz filter
- Max. Input (PWR).

Calibration Menu

- Calibration Reference
- Input User Reference
- Select Spacing, Temperature, Pressure and Density
- Mode (A, B, I, V)
- Calibration Level (A, B, I, V)
- Calibration Frequency
- Transducer Sensitivity
- Gain Adjustment

As well as making it easier to change software, this also means that if for any reason you have to make a master reset, you will not, for example, lose a previous calibration of the analyzer or have to go through the set-up of the interface again.

Master Reset

Chapter 3

Addendum to Volume 2

Key Control Codes	
Key	**Code**
Max. Input A Up	**M_I_A_U**
Max. Input A Down	**M_I_A_D**
Max. Input B Up	**M_I_B_U**
Max. Input B Down	**M_I_B_D**
Auto Range	**A_R**
Upper/Lower	**U_L**
Viewing Angle Up	**V_A_U**
Viewing Angle Down	**V_A_D**
Ampl. Scroll Up	**A_S_U**
Ampl. Scroll Down	**A_S_D**
Freq. Scroll Up	**F_S_U**
Freq. Scroll Down	**F_S_D**
Back Lighting On/Off	**B_L**
Hard Copy	**H_C**①
SRQ	**SRQ**
Local	**L**
Reset	**RES**

① Use the **P**rint_**S**creen**?** query. The following errors will occur if H_C is used:
IEEE: "IN ADDR MODE"
RS–232–C: "IN LISTEN MODE"
because the **"Hard Copy"** key is for manual use only and cannot be used when the interface is already in use. K_C H_C is kept as a command because the query K_C? can still answer with H_C as the last key-push

Table 5.1(b) K_C pushkeys and codes

5.3 BOOT and LOAD

Note:
BOOT(?) and **LOAD** can **only** be sent using the **IEEE** interface

Used in combination, the **BOOT(?)** and **LOAD** messages provide an alternative method of loading a new program and re-starting the analyzer. They have the same effect as a manual bootload, described in Volume 1, section 4.1.2 of this User Guide. Before attempting to load a program, you should send the **BOOT?** query message (see Fig. 5.3(a)) to ensure that the analyzer is ready.

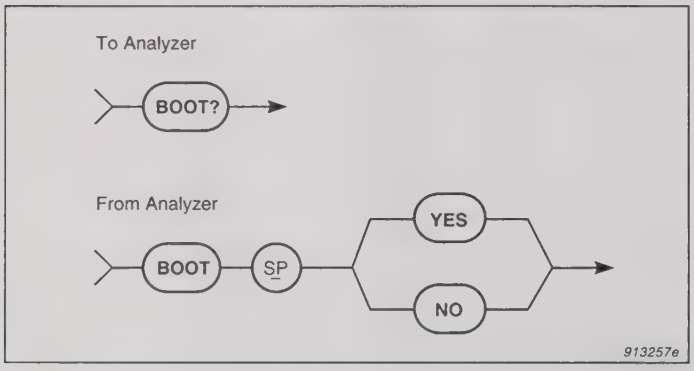


Fig. 5.3(a) Syntax for the BOOT? query message and analyzer response

If the analyzer responds with **YES**, then you can transfer the new program immediately, using the **LOAD** command message (see Fig.5.3(c)). If the response to **BOOT?** is **NO** then you must send the **BOOT** command message (Fig. 5.3(b)), before sending **LOAD**.

Note:
The **BOOT(?)** and **LOAD** messages must be sent in full. There are no mnemonic codes.

6.1 Measurement_Type (M_T)

The command message is used to set the **M_T** data field and display the **M**easurement_**T**ype menu. The query message returns a read-out of the current **M_T** data field.

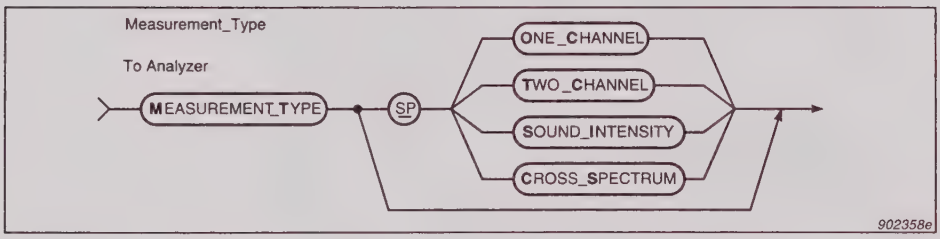


Fig. 6.1(a) Syntax for the M_T command message

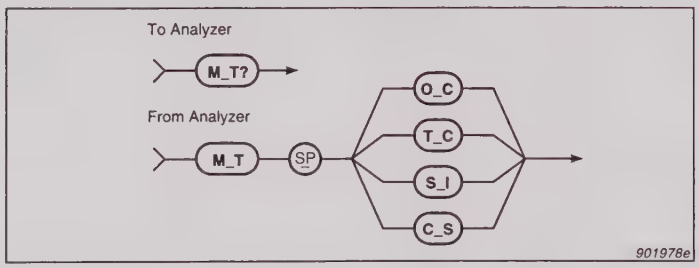


Fig. 6.1(b) Syntax for the M_T? query message and analyzer response

6.2 INput (IN)

The command message is used to set one or more of the **IN** data fields and display the **IN**put menu. The query message returns a read-out of all current **IN** data fields. The data fields and their settings are listed in Table 6.1.

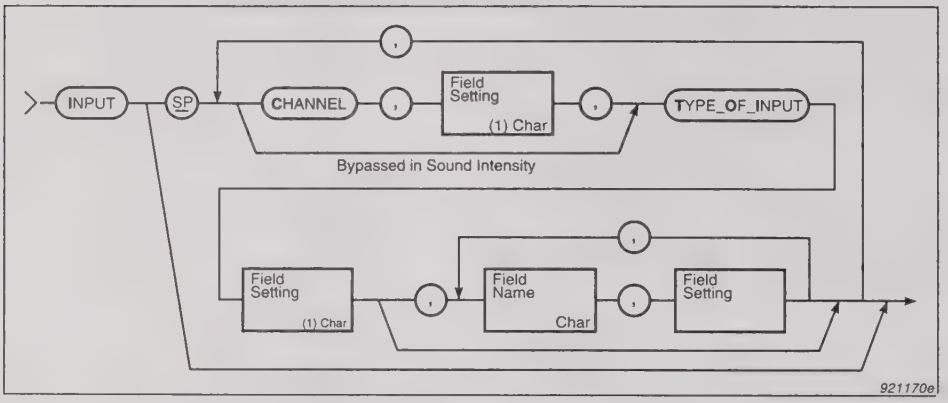


Fig. 6.2(a) Syntax for the IN command message

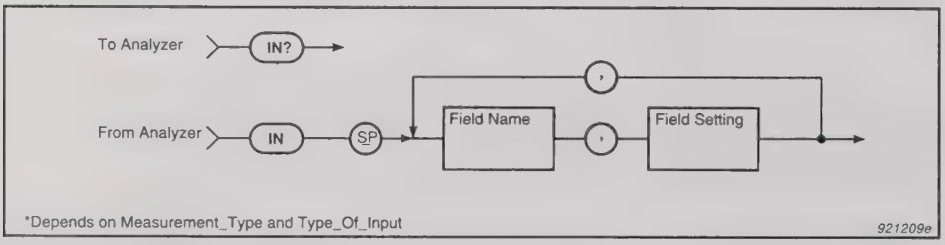


Fig. 6.2(b) Syntax for the IN? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Channel①	**A** **B**	Char.	Not selectable in Sound Intensity
Type_Of_Input	**D**irect **P**reamp **C**harge	Char.	 Not with A_Weighting
Filter	**H**igh_Pass_**0.3** **H**igh_Pass_**0.7** **H**igh_Pass_**2**0 **H**igh_Pass_**1**00 **A**_Weighting	Char.	Only with Charge Not with Charge
Low_Pass	**ON** **OF**f	Char.	Only with Charge
Max_Input	<numeric>	NR1/3② with suffix③	
Input_Protection	**ON** **OF**f	Char.	

① It is vital that Channel, Type of Input, Filter and Max. Input are set up in that order.
② Depends on whether Y-axis unit is dB or Absolute
③ With suffix unit dB or Absolute, Max_Input is independent of Y-axis unit

Table 6.1 INput data fields and codes

6.3 Filter_Bandwidth (F_B)

The command message is used to set one or more **F_B** data fields and to display the **F**ilter_**B**andwidth menu. The query message returns a read-out of all current **F_B** data fields. Table. 6.2(a) shows legal combinations of **B**andwidth and **U**pper_**F**requency. The data fields and their settings are listed in Table 6.2(b).

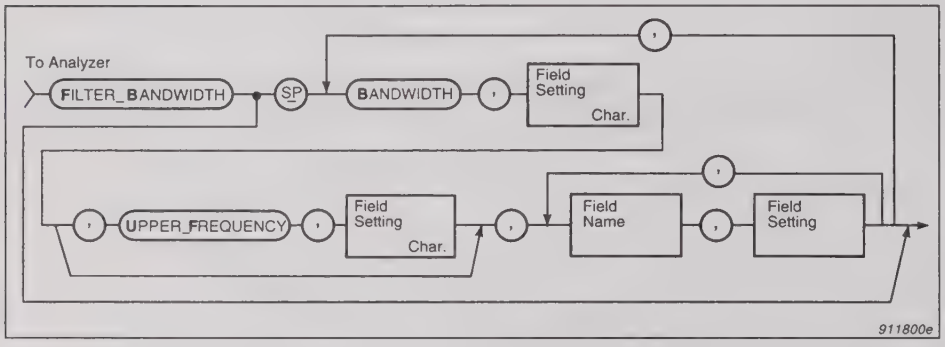


Fig. 6.3(a) Syntax for the F_B command message

Note:
The **B**andwidth and **U**pper_**F**requency fields must be set up in the order shown in Fig. 6.3(a).

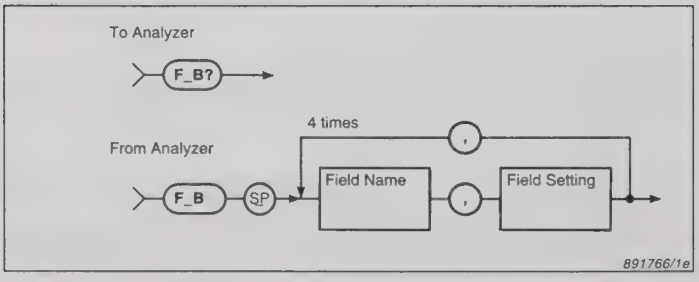


Fig. 6.3(b) Syntax for F_B? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Reference	**A** **B** **Re_Im** **P** **V** **I_J**	Char.	Cross mode only } Intensity
User_**R**eference		NR3	
Nominal_**S**pacing	1 to 500	NR1	
Ambient_**T**emperature	–25 to 100	NR2	°C
Ambient_**P**ressure	650 to 1100	NR2	Default unit hPa
Air_**D**ensity	0.0001 to 12	NR3 (with suffix)	Default unit kg/m
User_**D**ensity	0.0001 to 12	NR3 (with suffix)	Default unit kg/m
Mode	**A** **B** **A_B** **I** **V**	Char.	In 1-ch. mode, only A is available. A_B is only available in intensity mode. I and V are only for verification of intensity calibration
Calibrator_**L**evel		NR3	See note in Input message for Max_Input
Calibrator_**F**requency		NR3	
Transducer_**S**ensitivity		NR3	
Gain_**A**djustment		NR3	See note in Input message for Max_Input
Calibration_**A**vg_**T**ime	2; 4; 8; 16	NR1	Time in seconds
Auto_**C**alibration	**S**tart	Char.	Input only
Verification_**A**vg_**T**ime	2; 4; 8; 16	NR1	Time in seconds
Auto_**V**erification	**S**tart	Char.	Input only

Table 6.3 CAlibration data fields and codes

6.5 COrrection (CO)

The command message is used to set one or more specified **CO** data fields and display the Correction menu (page 4 of the Calibration menu). The query message returns a read-out of the current **CO** data fields. The data fields and their settings are listed in Table 6.4.

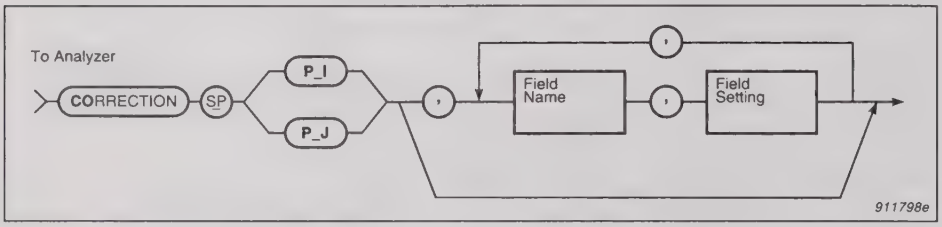


*Fig. 6.5(a) Syntax for the **CO** command message*

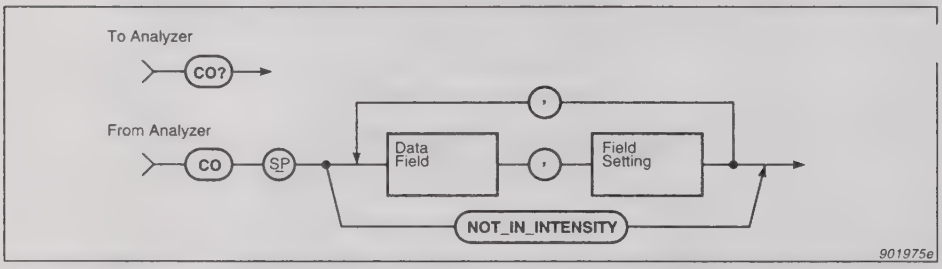


*Fig. 6.5(b) Syntax for the **CO?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Range_High_Frequency		NR3	
Range_Low_Frequency		NR3	
Averaging_Time	24H to 1ms	NR3	
Correction	**ON** **OFf**	Char.	
Save_Correction	1–999	NR1	Input message only
Recall_Correction	1–999	NR1	Input message only

*Table 6.4 **COrrection** data fields and codes*

6.6 AVeraging (AV)

The command message is used to set one or more specified **AV** data fields and display the **AV**eraging menu. The query messag. **AV?** returns a read-out of all current **AV** data fields. The data fields and their settings are listed in Table 6.5.

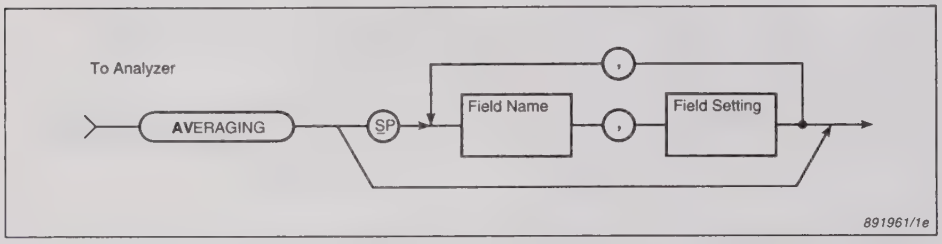


Fig. 6.6(a) Syntax for the AV command message

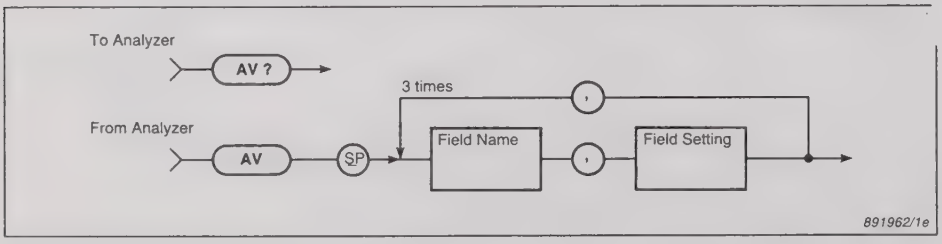


Fig. 6.6(b) Syntax for the AV? query message and analyzer response

6.8 Hold (H)

The command message is used to set one or more specified H data fields and display the Hold menu. The query message returns a read-out of the current H data fields. The data fields and their settings are listed in Table 6.7.

Note:
"2" is not available in single channel mode.

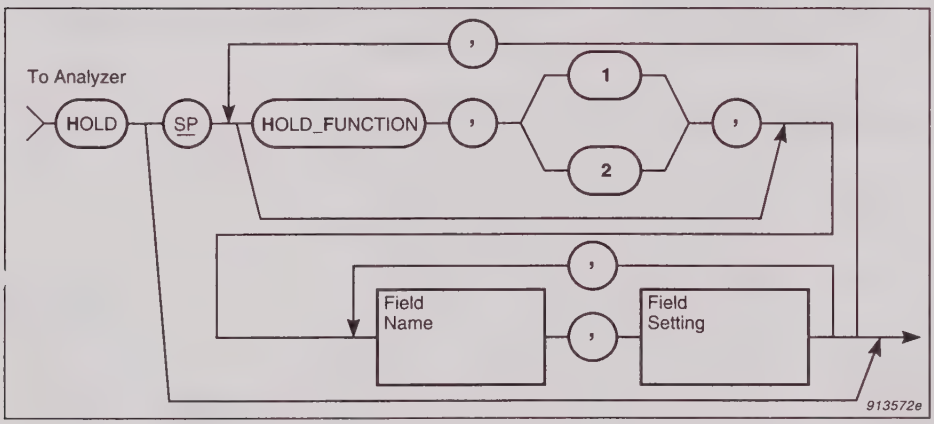


*Fig. 6.8(a) Syntax for the **H** command message*

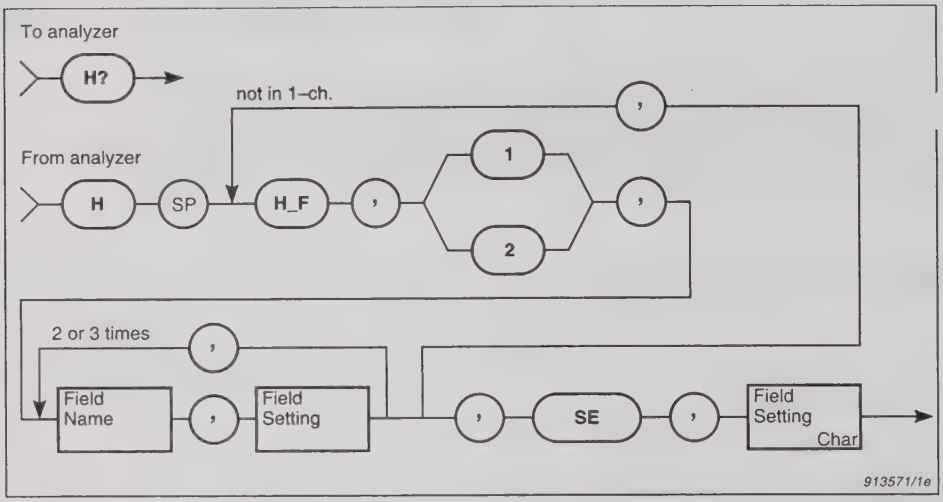


*Fig. 6.8(b) Syntax for the **H?** query message and analyzer response*

Field Name	Field Setting	Data Type	Comments
Hold_Function	1 or 2	NR1	Ignored in 1-ch.
Type	**MAx** **MIn**	Char.	
MOde	Inactive **All_C**hannels **A_L_C**hannel **W_C**hannel **B**and_**P**ass_**F**ilter	Char.	
Band_**P**ass_**F**ilter_ **C**entre_**F**requency		NR3 (with suffix)	Automatically rounded to nearest centre frequency. Only in **B**and_**P**ass_**F**ilter **MO**de
SPectrum	**A**uto_**A** **A**uto_**B** **C**ross_**R** **C**ross_**I** **M**ean_**P** Velocity **R**eac_**J** Intensity	Char.	Ignored in 1-ch. 2-ch. } Cross } Intensity
SElect	**H**old **D**ata_Exclude	Char.	

Table 6.7 Hold data fields and codes

6.9 Spectrum_Weighting (S_W)

The command message is used to set one or more specified **S_W** data fields and display the Spectrum_Weighting menu. The **S_W?** query message returns a read-out of all current **S_W** data fields. The data fields and their settings are listed in Table 6.8.

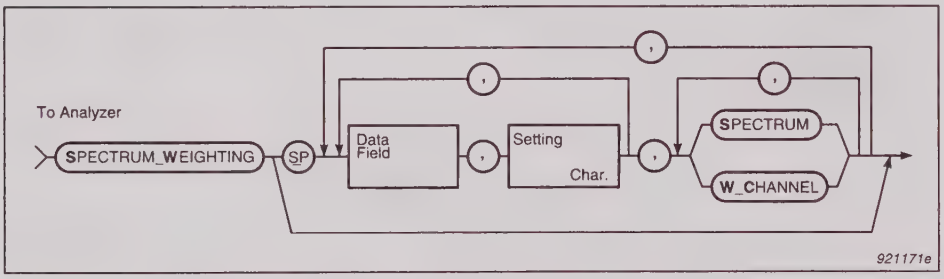


Fig. 6.9(a) Syntax for the S_W command message

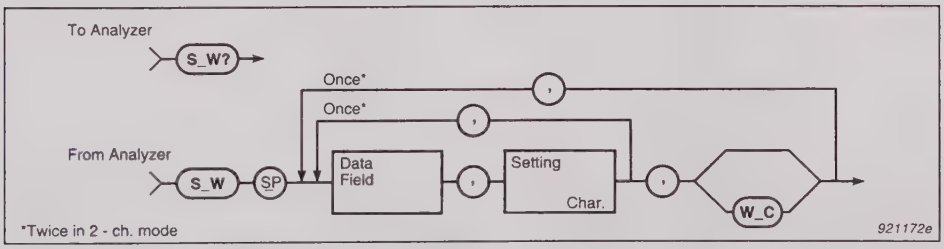


Fig. 6.9(b) Syntax for the S_W query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Weight	Linear_Weighting U1 U2 U3 U4 A_Weighting B_Weighting C_Weighting D_Weighting	Char.	
Inverse	ON OFf	Char.	
Auto_Spectrum	A B	Char.	Only in 2-ch. mode

Table 6.8 Spectrum_Weighting data fields and codes

Field Name	Field Setting	Data Type	Comments
Measurement_**S**equence	**DCR** **DRC** **CDR** **CRD** **RDC** **RCD**	Char.	
Trigger_Level		NR3	See note in INput message for Max_ Input
Trigger_Channel	**A_L_C**hannel **W**_Channel Band_Pass_**F**ilter	Char.	
Band_Pass_Filter_ Channel_Frequency	<numeric> { **MI** / **H**z / **K**Hz }	NR3 (with suffix)	Defaults to Hertz. Use **MI** (upper case) or **m** (lower case) for millihertz
SLope	**NE**gative **PO**sitive	Char.	
SPectrum	**A**uto_**A** **A**uto_**B** **C**ross_**R** **C**ross_**I** **M**ean_**P** Velocity **R**eactive_**J** Intensity	Char.	1-ch., 2-ch., Cross 2-ch., Cross Cross Cross Intensity Intensity Intensity Intensity
Clock_**H**our	**AM**, <integer> **PM**, <integer> <integer>	Char. NR1	HHMMSS Integer only defaults to 24hr clock
Repetition_**I**nterval	<numeric> { **M**inutes / **S**econds }	NR2 (with suffix)	Default is seconds

Table 6.12(b) Trigger data fields and codes

6.16 Preselected_SEtup (P_SE)

The command message is used to send a Preselected Setup to the analyzer in block data (binary) format and to change between the different Preselected Setups. You can activate a **M**easurement setup, **D**isplay setup or the **C**alibration setup from either default values or a set of stored values. The query message returns a readout of a specified setup in binary or ASCII format. The data fields and their settings are listed in Table 6.13.

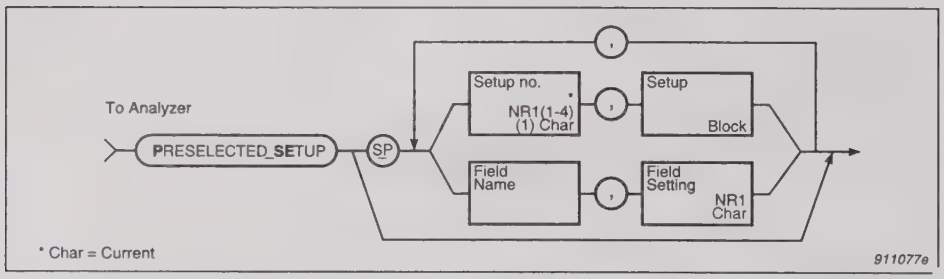


Fig. 6.16(a) Syntax for the P_SE command message

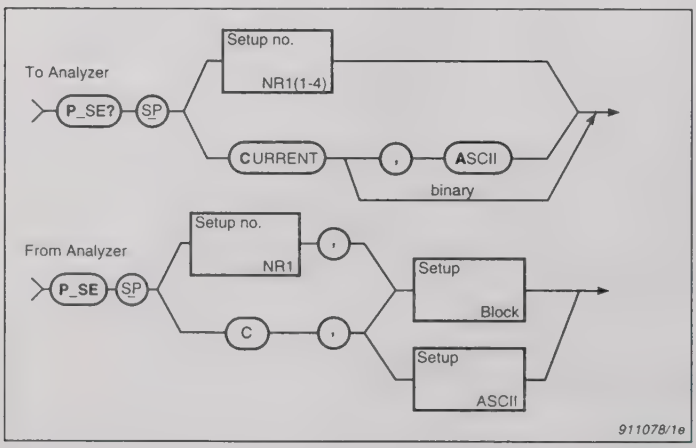


Fig. 6.16(b) Syntax for the P_SE? query message and analyzer response

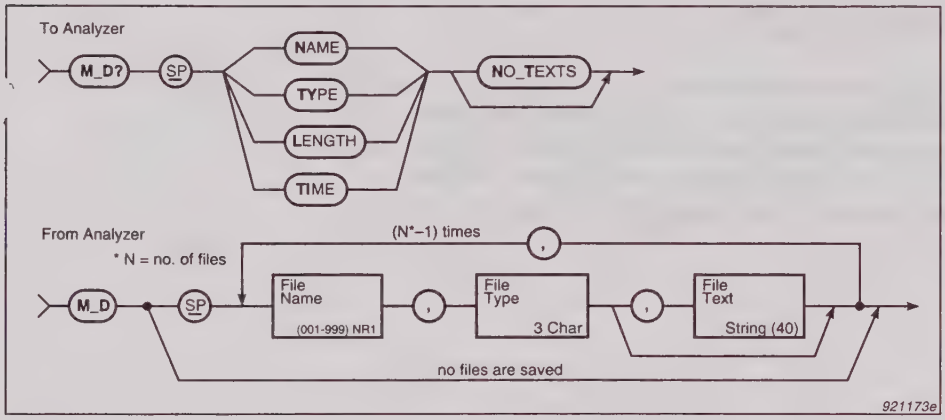


Fig. 6.17(c) Syntax for the M_D? file list query message and analyzer response

6.17.4 M_D? Overload Query Message

This query message is used to determine whether a particular file contains an overload. This could be used after a multispectrum measurement, to determine whether an overload has occurred in one of the spectra.

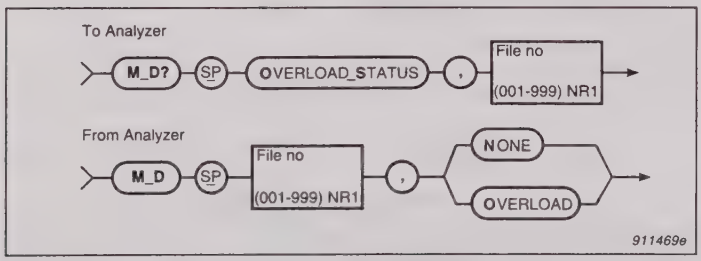


Fig. 6.17(d) Syntax for the M_D? Overload query message and analyzer response

6.18 Boom_Mux (B_M)

The command message is used to set one or more specified **B_M** data fields and display the **B**oom_**M**ux application menus. The query message returns a read-out of all the **B_M C**ommon_**S**etup data fields, and either the **D**ecay or **SP**l fields, depending on which has been selected. The data fields and their settings are listed in Table 6.14.

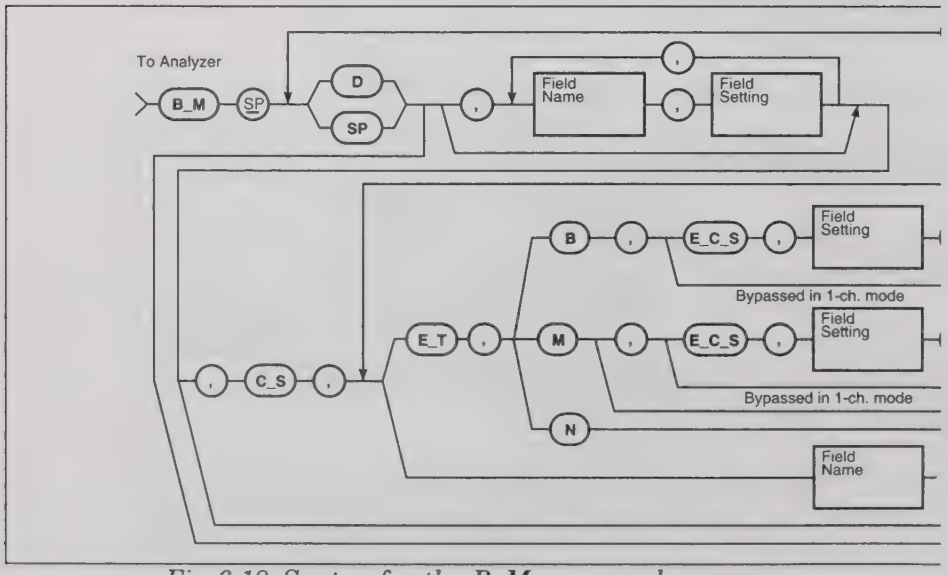


Fig.6.18 Syntax for the B_M command message

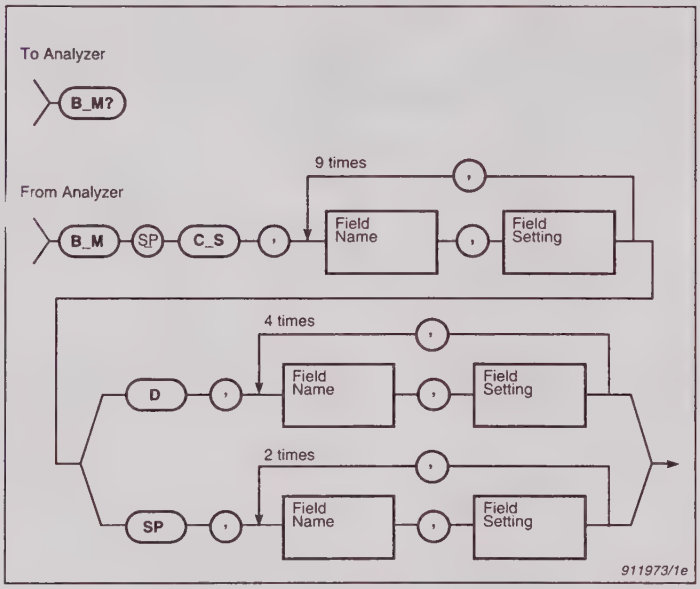
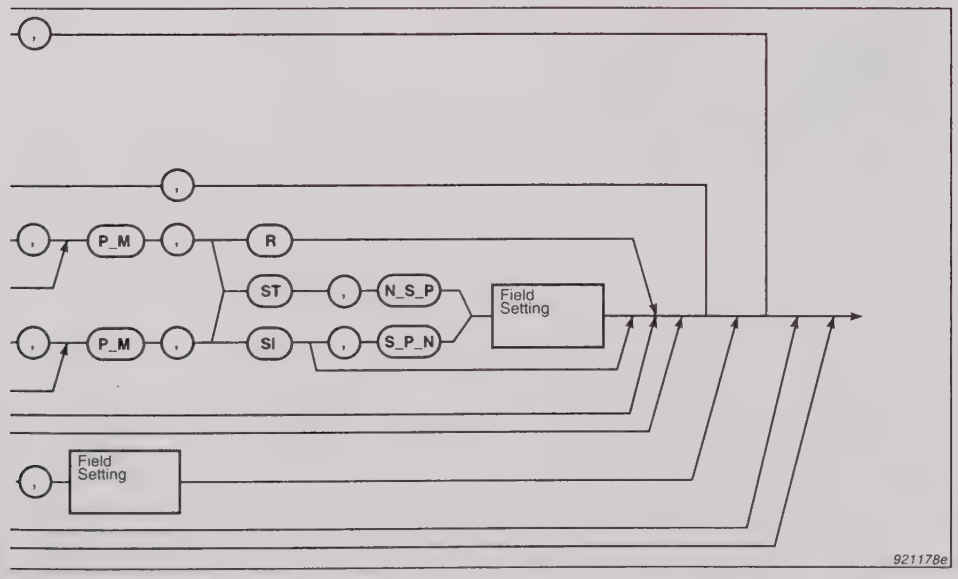


Fig. 6.19 Syntax for the B_M? query message and analyzer response



Field Name	Field Setting	Data Type	Comments
Boom_Mux_Sound_ Source_Appl	Active Inactive	Char.	Common_Setup
Sound_Source	A B A&B OFf	Char. NR1	Only SPI
Auto_Range	ON OFf	Char.	
Auto_Range_Time	<numeric>	NR3	
Delaybefore_ Measurement_Start	<numeric>	NR1	
Equipment_Type	Boom Mux None	Char.	
Equipment_Channel_ Select	A B A&B	Char.	Not in 1-ch. mode
Positioning_Mode	SIngle STep Rotating	Char.	
Single_Position_Number	<numeric>	NR1	
Number_Step_Positions	<numeric>	NR1	

Table 6.14(a) Boom_Mux data fields and codes with Common_Setup

Field Name	Field Setting	Data Type	Comments
Sound_Source_On_Time	<numeric>	NR1	Decay
Averaging_Mode	Linear Exponential	Char.	
Time_Interval_ Between_Spectra	<numeric>	NR3	
Spectraper_Excitation	<numeric>	NR1	
Spectrabefore_Sound_ Source_Off	<numeric>	NR1	
Excitationsper_Position	<numeric>	NR1	
Sound_Source_On_ Timebefore_Meas	<numeric>	NR1	SPl
Measurement_ Timeper_Step_Rota	<numeric>	NR3	
Device_Settling_Time	<numeric>	NR3	

Table 6.14(b) Boom_Mux data fields and codes with Decay and SPL

7.5 IDentify? (ID?)

IDentify? (query only) returns a read-out of the instrument type. If version B of the message is sent, then the input module identification (analog type) and the software version number are also returned.

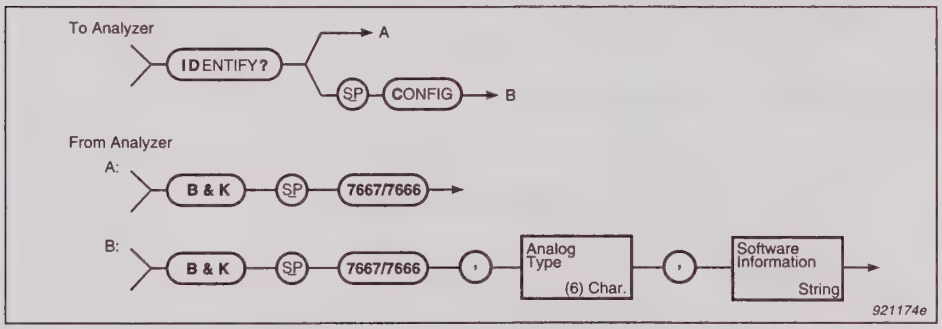


Fig. 7.5 Syntax for the ID? query message and analyzer response

Example:

The controller sends:

```
ID? C
```

The analyzer returns:

```
B&K 7667,ZN0497,"VP7342,101,1,100,101,100,111"
```

7.6 Update (U)

Update (command only) is used to choose the update mode for the 2144 display. The alternatives are listed in Table 7.4.

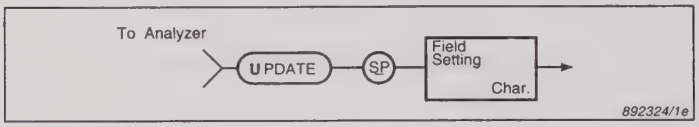


Fig. 7.6 Syntax for the U command message

Field Setting	Data Type	Comments
Update_Meas	Char.	Only displays changes in the measurement menus, i.e. Measurement Mode, Calibration and Internal Trigger
Update_All	Char.	Displays all changes and the "affected" menu. This is the default setting

Table 7.4 Update data fields

Note:
Changing the update status automatically sets the analyzer in measurement mode.

7.9 Averaging_Control (A_C)

Averaging_Control (command only) is used to start, continue (proceed) and stop an averaging operation.

Note:
If **A_C STA**rt is received when the analyzer is not in measurement mode, it switches to measurement mode automatically, and then starts the measurement.

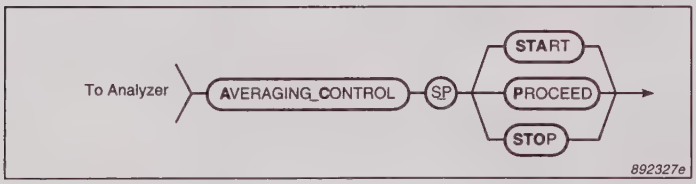


Fig. 7.9 Syntax for the A_C command message

7.10 Measurement_Mode (M_M)

Measurement_Mode is used to set one or more specified M_M data fields and to display the Measurement_Mode menu. The command data fields and their settings are listed in Tables 7.5(a) and 7.5(b). The query message returns a read-out of the data fields listed in Table 7.5(c).

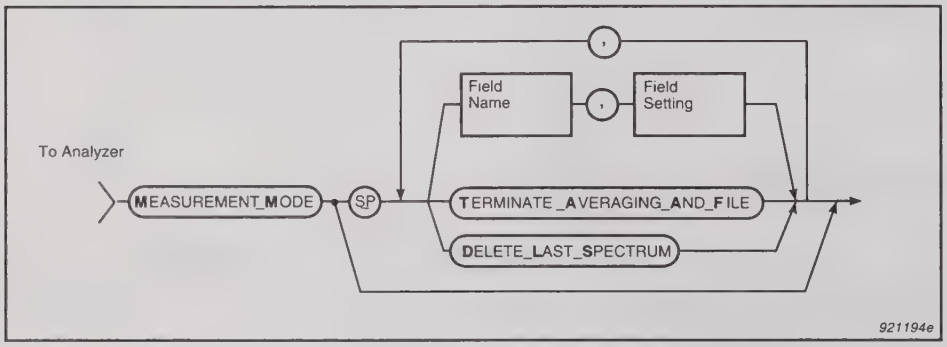


Fig. 7.10(a) Syntax for the M_M command message

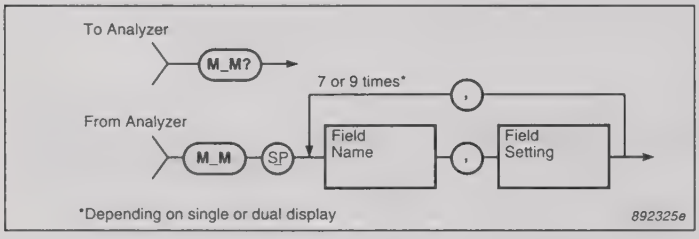


Fig. 7.10(b) Syntax for the M_M query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Centre_Frequency Centre_Frequency_ Upper Centre_Frequency_ Lower	<numeric> { m[1]Hz / Hz / KHz	NR3 (with suffix)	Default is Hertz. Range of centre frequencies depends on bandwidth
Align_Cursor	ON OFf	Char.	
Select_Spectrum_Type Select_Spectrum_Type Upper Select_Spectrum_Type Lower	Auto_A Auto_B Cross_Re Cross_Im Mean_Pressure Velocity Reactive_J Intensity Phase Magnitude Coherence H1 H2 H3	Char.	1-ch., 2-ch., Cross 2-ch., Cross Cross Cross Intensity Intensity Intensity Intensity Intensity, Cross Intensity, Cross Intensity, Cross Cross Cross Cross
Averaging_Time	<numeric> { Seconds / milliseconds	NR3 (with suffix)	Default is seconds. 18 discrete values from $^1/_{256}$ to 512 s in binary sequence for exponential averaging

[1] Lower case m or MI/MS for milli-

Table 7.5(a) Measurement_Mode data fields and settings (command)

Field Name	Field Setting	Data Type	Comments
Monitor_Spectrum_No		NR1	Only in Gated Pass measurement
Save	1–999	NR1	Not used in Normal
Recall Recallto_Upper Recallto_Lower	1.000–999.999	NR1 NR2	NR2 for a multispectrum
Open_File	1–999	NR1	Only in Normal and Matrix, real-time
Delete_Last_Spectrum	[none]①	Char.	Only when a file is open
Terminate_Averaging_And_File	[none]①	–	Only in Normal and Matrix, real-time
Pass_No		NR1	Only in Manual Pass measurements
Spectrum_HOld	**ON** **OFf**	Char.	Only when trigger is inactive
Display Display_Upper Display_Lower	**HO**ld **C**ontinue	Char.	
Elapsed_Time②		NR2	
Averaging_Status②		Char.	

① Not a code
② Exist as input messages but have no effect

Table 7.5(b) Measurement_Mode data fields and settings (command)

Field Name	Field Setting	Data Type	Comments
Save		NR1	This is the figure displayed after "SAVE IN" on the screen of the analyzer
Elapsed_Time		NR2	
Averaging_Status	REady RUnning Paused Finished Waiting Settling Auto_Range	Char.	This field can also be read out using the Actual_Status message. See section 7.3
Pass_No		NR1	
Align_Cursor	ON OFf	Char.	
Select_Spectrum_Type_Upper Select_Spectrum_Type_Lower	A_A A_B C_R C_I M_P V R_J I P M C H1 H2 H3	Char.	
Spectrum_Hold	ON OFf	Char.	
Display_Upper Display_Lower	HOld Continue	Char.	

Table 7.5(c) Measurement_Mode data fields and settings (query)

7.11 Max_Input (M_I)

The **M**ax_**I**nput command message is used to set the input attenuator, either in single steps or by selecting a specified setting. The query message returns a read-out of the current setting.

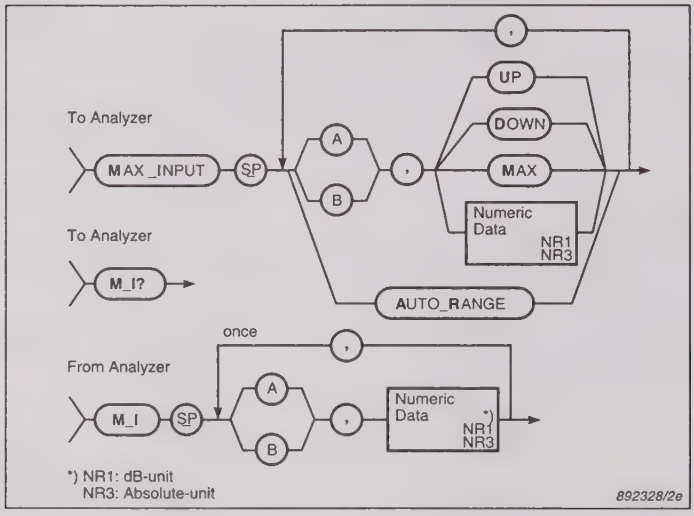


Fig. 7.11 Syntax for the M_I messages

Note:
Max_Input Auto_Range will almost always jump directly to the measurement mode and start the auto-range function. The exceptions are for pages 2 to 4 of the Calibration menu and the Internal Trigger menu.

Chapter 8

Status, Result & Display Messages

8.1 Error? (ER?) 8-2

8.2 Status_Byte? (S_B?) 8-4

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8.4 Measurement_Data_Transfer (M_D_T) 8-6

8.5 Data_Memory_Read? (D_M_R?) 8-9

8.6 Current_Spectrum_Read? (C_S_R?) 8-11

8.7 Print_Screen? (P_SC?) 8-13

8.8 Measure-and Readout? (M_R?) 8-15

8.1 ERror? (ER?)

ERror? (query only) returns information concerning the most recent analyzer error. This error record comprises the error number (see Chapter 9 for a full list of 2144 interface error messages) and a brief description of the error. It is in the form of a character string of up to 80 characters. The error record is described below, with examples. Fig. 8.1 shows the syntax for the **ERror?** query.

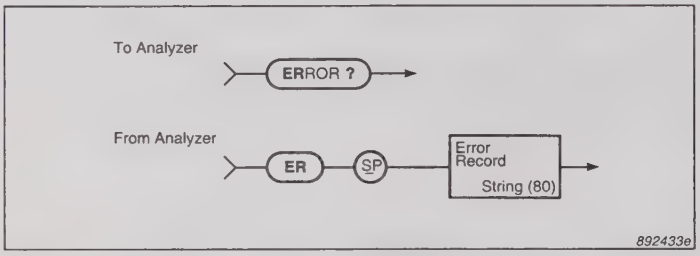

Fig. 8.1 Syntax for the ER? query

After the error record is read out, the record is deleted. If no error has occurred since the last read-out of **ER?**, the analyzer returns the message:

```
ER "ERR 0000:  NO ERROR "
```

Error Record:

```
<">
Header:           4 char (1-4)
Error_Number:     4 char (5-8)
Error_Trail:      2 char (9-10)
Error_Text:      20 char (11-30)
Message_Header:   7 char (31-37)1) 2)
Error_Buffer:    43 char (38-80)1) 3)
<">
```

Example:

```
ER "ERR 0060:  UNKNOWN INDEX      F_B   :
f_b Bandwidth,oct_3,pper_freq,"
```

---

1) Message_Header and Error_Buffer are left out if the error is the result of a manual operation.

   Example: "ERR 0060: UNKNOWN INDEX"

2) Message_Header is left out if the error occurs on receipt of a header, in which case Error_Buffer is located from 31 to 44.

   Example: "ERR 0060: UNKNOWN INDEX g_b"

3) Left out if Error_Stop No is chosen.

   Example: "ERR 0060: UNKNOWN INDEX F_B :"

8.2 Status_Byte? (S_B?)

Status_Byte? (query only) returns a read-out of the 2144 status byte. This is similar to the effect of a serial poll performed via the IEEE interface. Busy (bit 5) will always be set. The value read out is the decimal value of the bit pattern.

Note:
When an error has locked up the bus, the query S_B? cannot be used. However, Serial_Poll is always available.

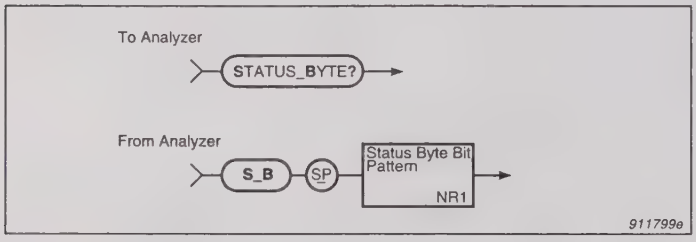

Fig.8.2 Syntax for the S_B? query

Example:

If you send:

```
S_B?
```

the analyzer responds (for example) with:

```
S_B  144
```

This represents 10010000, i.e. bit 5 (busy) and bit 8 (key pressed) are set.

For the content of the status byte see Service_Request_Enable (section 7.1)

8.3 Actual_Status? (A_S?)

Actual_Status? (query only) returns a read-out of the status of one of the data fields listed in Table 8.1 (**Averaging**, **Input_Overload** or **Global_Warning**). The syntax of the **Actual_Status?** query is described in Fig. 8.3.

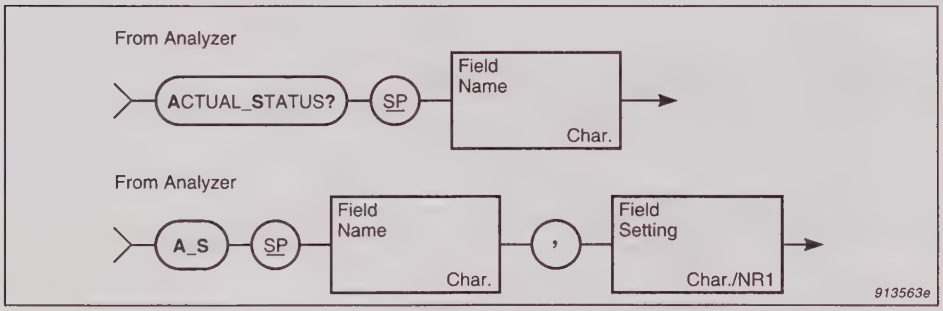

Fig. 8.3 Syntax for the A_S? query

Field Name	Field Setting	Data Type	Comments
Averaging	**RE**ady **RU**nning **P**aused **F**inished **W**aiting **S**ettling **A**uto_Range **N**one	Char.	
Input_**O**verload		NR1	8-bits status①: Bit 1 (LSB) Common Bit 2 Channel A Bit 3 Channel B Bits 4–8 Not used
Global_**W**arning	**L**ow_**P**ower **I**nput_**P**rotection **N**one	Char.	

① Once an overload has been captured, the information is kept until it is read out. We therefore recommend making a dummy reading before starting a measurement to avoid old overload information

Table 8.1 A_S data fields and settings

8.4 Spectrum_Data (S_D)

The Spectrum_Data message is used to load specified spectra into, and to read spectra out of, the 2144 spectrum memory. The spectra are input and output in the form of binary block data.

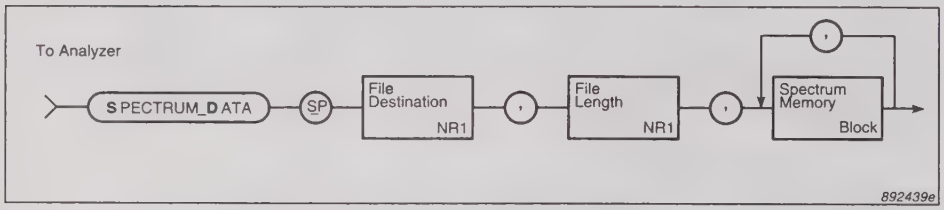

Fig.8.4(a) Syntax for the S_D command message

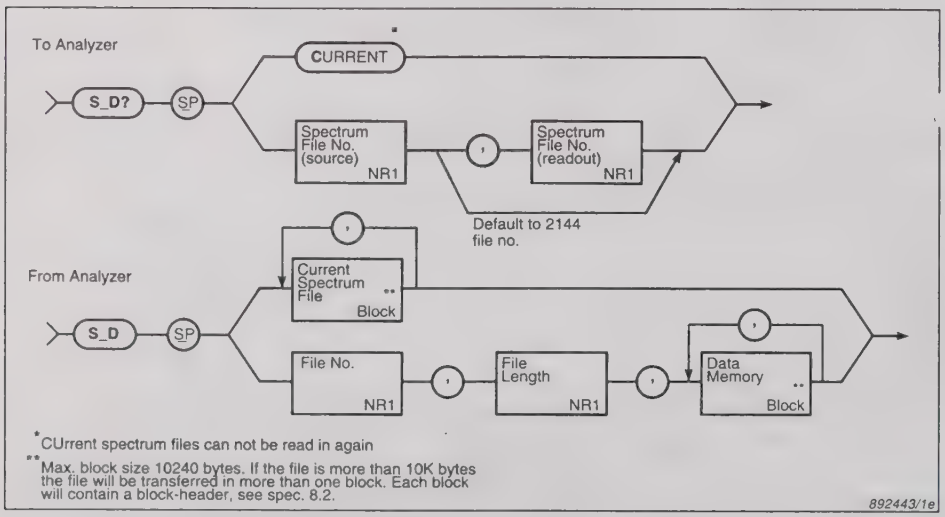

Fig.8.4(b) Syntax for the S_D? query and analyzer response

Note:
See sections 4.2.4, 7.14 and Chapter 10, for further details of the format for block data.

8.5 Data_Memory_Read? (D_M_R?)

Data_Memory_Read? (query only) returns a read-out of a specified spectrum or slice from spectrum memory. This read-out comprises a description followed by a number of Y values (dB or absolute units).

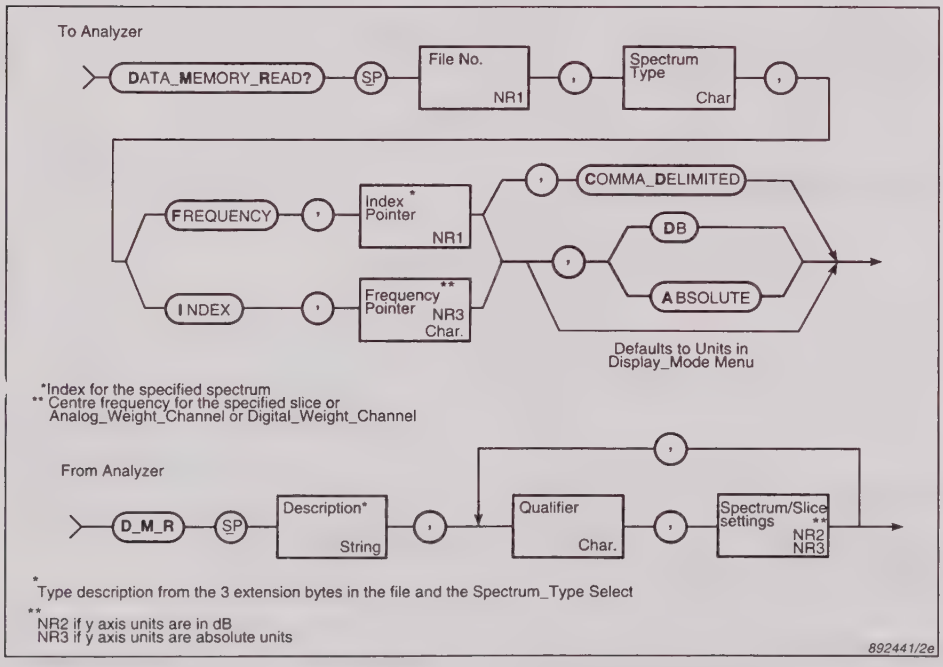

Fig. 8.5 Syntax for the D_M_R? query and analyzer response

Spectrum_Type can be:

Auto_A
Auto_B
Cross_Re
Cross_Im
Mean_Press
Velocity
Reac_J
Intensity

Qualifier can be:

V=Valid
O=Overload
B=Bad
N=Negative
P=Positive

Examples:

To obtain a read-out from spectrum memory in comma delimited format, the controller might send:

```
D_M_R? 1,A_A,F,1,C_D
```

The analyzer responds with (for example):

```
D_M_R ...
"Spectrum no.",  "1"
"0.50","V",-369.04
"1.00","V",46.54
"2.00","V",80.53
.
.
.
.
"W","V",73.63<SUB>
```

To obtain a read-out from spectrum memory in Normal ASCII format, the controller might send:

```
D_M_R? 1,A_A,F,1,DB
```

The analyzer responds with (for example):

```
D_M_R "SIMPLE,2CH.AUTOSPECTRUM,1/3  OCTAVE,
  AUTO_A",V-256.00,V,-25  etc.
```

8.6 Current_Spectrum_Read (C_S_R?)

Current_Spectrum_Read? (query only) returns a read-out of results from the current displayed spectrum. The start frequency of the read-out, which spectrum, and the number of values read out can be specified. The read-out may be in dB or absolute units. The data fields and codes are listed in Table 8.2.

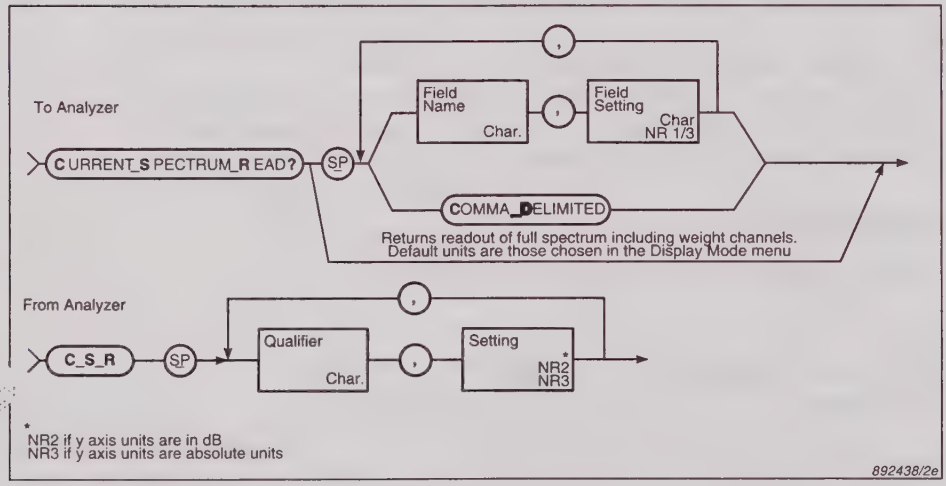

Fig.8.6 Syntax for the C_S_R? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
STart	<numeric> **A**nalog_**W**eight_**C**hannel **D**igital_**W**eight_**C**hannel	NR3 Char.	Default is the first frequency band
Number	<numeric> **M**ax	NR1 Char.	Default is one band
Y_Axis_**U**nit	**D**b **A**bsolute	Char.	Defaults to units chosen in Display Mode menu
SPectrum	**U**pper **L**ower	Char.	Defaults chosen in Measurement Mode

Table 8.2 List of Current_Spectrum_Read? data fields and codes

Qualifier can be:

V=Valid
O=Overload
B=Bad
P=Positive
N=Negative

Examples:

Full Spectrum
To obtain a readout of the current spectrum in full, the controller sends:

```
C_S_R?
```

The analyzer responds with (for example).

```
C_S_R V,79.75,V,81.91,V,86.41,V,68.23,V
```
etc.

Partial Readout
To obtain a readout of a defined part of the current spectrum the controller might send:

```
C_S_R? STA,1K,N,3,Y_A_U,DB
```

The analyzer responds with (for example):

```
C_S_R V,119.94,V,98.00,V,79.28
```

If comma delimited format is used, the output format is the same as for D_M_R.

8.8 Measure-and_Readout (M_R)

Measure-and_**R**eadout allows measured data to be stored in memory buffer on receipt of an external trigger. The buffer content must be read by the controller before the new measurement ha finished, otherwise data will be lost.

Note:
Although an external trigger is needed to initiate the measurement, **M_R** requires that the analyzer operates with **T**rigger_-**M**ode **I**nactive.

Fig.8.8 shows the syntax for the **M_R** command message which is used when the host computer controls the read-out. Fig.8.9 shows the syntax for the corresponding **M_R?** query message and the analyzer response.

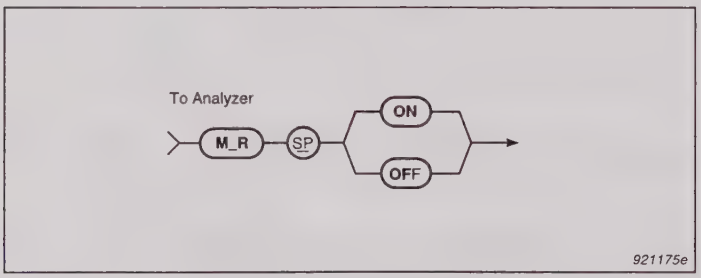

Fig.8.8 Syntax for the M_R command message

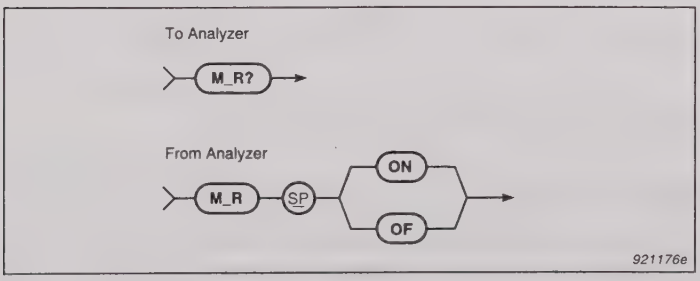

Fig.8.9 Syntax for the M_R query message and analyzer response

The **M_R?** query message can be extended with parameters for the number of read-outs and the required averaging time as shown in Fig.8.10. In this case, the analyzer responds with the specified number of spectra (as block data) each measured ove the selected linear averaging time.

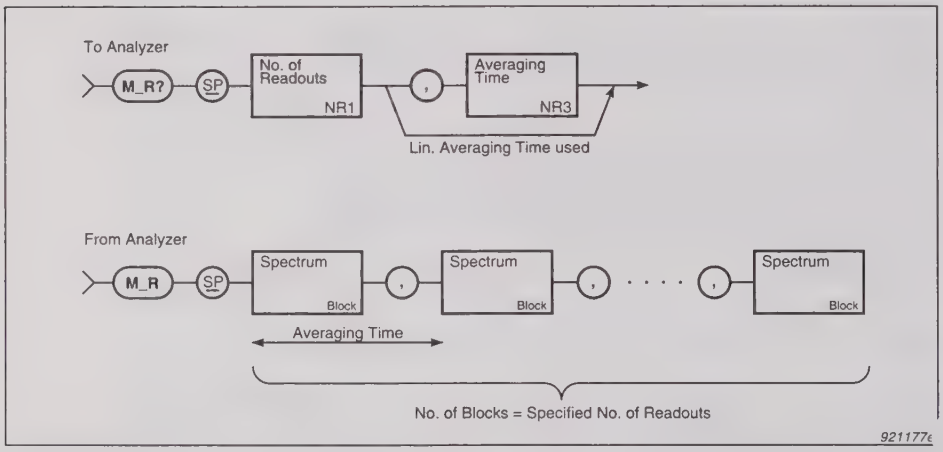

Fig.8.10 Syntax for the M_R? xx, (yy.y) query message and analyzer response

The measurement procedures required when using **M_R** and **M_R?** with parameters are basically different, as described below.

Use of M_R (see Fig.8.8)

1. Before starting the measurement, verify that trigger mode is inactive.
2. Select the linear averaging time which equals the required time interval between spectra.
3. Set Measure-and_Readout to ON.
4. Enable measurements by sending **A**veraging_**C**ontrol **STA**rt, which implies that measurements will be started when an external trigger is received.

When the first measurement is complete, the result is stored in a buffer and, at the same time, the next measurement is imme-

diately started. The data held in the buffer must be read out using either **C**urrent_**S**pectrum_**R**ead? or **S**pectrum_**D**ata? before the next measurement is complete. If not, **data for the new measurement will be lost!**

Operation (data read-out during ongoing measurements) proceeds in this way as long as required.

The normal measurement procedure is:

1. **M_R ON**.
2. **A_C STA**.
3. Trigger the analyzer – This occurs on the negative slope of the signal applied to the **"Ext. Trigger"** socket on the rear panel of the analyzer.
4. Wait for data – To determine when data are available, use either **AW**ait **D**ata_**A**vailable or perform a serial poll. **AW D_A** locks the IEEE interface until the buffer memory holds data. During a serial poll, bit no. 1 of the status byte will be set when data are available.
5. **S_D? C** – The analyzer response is block data. If you use **C_S_R?** instead, you can select output in ASCII or comma delimited format.
6. Repeat from 4 as required – The data captured in point 5 can be processed in the controller before looping to point 4. The time taken for data read-out and processing should be less than the selected linear averaging time (time interval between spectra).
7. **A_C STO**.
8. **M_R OF**.

Use of M_R? (see Figs. 8.9 and 8.10)

If **M_R?** is sent without parameters, the analyzer response only states whether the special read-out mode is active (**ON**) or disabled (**OF**f).

The query message can also be extended with parameters – the required number of read-outs and the averaging time. If the averaging time is not set, measurements will be made over the currently valid linear averaging time.

When the analyzer is triggered, it responds with a sequence of block data representing spectra, each measured over the specified averaging time. The number of blocks is equal to the specified number of read-outs, as indicated in Fig.8.10.

In this measurement mode, you don't need to activate the M_R function, i.e. **M_R ON** is not required. The extended query function does this automatically and also generates the **A_C STA** command, enabling the start of measurement when an external trigger is received.

When the measurement series is complete, M_R is automatically disabled again.

Example:
To obtain a read-out of 50 spectra, each measured over an averaging time of 500 ms, the controller sends:

```
M_R? 50,0.5
     |   └── Averaging Time (NR3)
     └────── No. of spectra
```

Notes:

- The averaging time (final parameter) can be specified in other ways, e.g. 500E–3, 5m, etc. Refer to the syntax for NR3.
- To avoid loss of spectra, the selected averaging time must be longer than the time needed for data transfer (read-out of block data).
- The data have the same format as for Spectrum_Data Current.

9.4 List of Error Messages (cont'd)

Error no.	Error Message	Description
047	SYNTAX ERROR	The syntax diagram has not been followed carefully
048	ILLEGAL FILE	The contents of the file do not match with files generated by this analyzer
049	BOOM/MUX ACTIVE	When Boom/Mux is active, certain parameters cannot be changed
050	FILE NOT OPEN	Illegal attempt to delete the last spectrum after the file has been closed

Table 9.1(c) 2144 interface error messages

Brüel & Kjær

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Telephone: +45 42 80 05 00 · Telex: 37316 bruka dk · Fax: +45 42 80 14 05

Australia (02) 450-2066 · Austria 02235/7550*0 · Belgium 02·242 97 45 · Brazil (011) 246-8149/246-8166
Canada (514) 695-8225 · Czechoslovakia 02-311 48 40/311 48 41 · Finland (90) 80 17 044 · France (1) 64 57 2010
Germany 04106/70 95-0 · Great Britain (081) 954-2366 · Holland 03402-39994 · Hong Kong 548 7486
Hungary (1) 133 83 05/133 89 29 · Italy (02) 57 60 41 41 · Japan 03-5420-7302 · Republic of Korea (02) 554-0605
Norway 02-90 44 10 · Poland (0-22) 42 10 52 · Portugal (1) 65 92 56/65 92 80 · Singapore 225 8533 · Spain (91) 268 10 00
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Technical Documentation

Dual Channel Real-time Frequency Analyzer
Type 2144

Vol. 2: Interface

User Guide · User Guide · User Guide ·

User Guide
Dual Channel Real-time Frequency Analyzer
Type 2144

From serial no. 1614490
using system software VP7278

January 1992

Brüel & Kjær

BB 0783–11

Safety Considerations

This apparatus has been designed and tested according to IEC Publication 348, *Safety Requirements for Electronic Measuring Apparatus*, and has been supplied in safe condition. The present User's Guide contains information and warnings which should be followed by the user to ensure safe operation and to retain the apparatus in safe condition. Special note should be made of the following:

Powering the Apparatus

Before each use of the Power Supply ZG 0199 with the apparatus, check that it is set to match the available mains voltage and that the correct fuse is installed.

Safety Symbols

⚠ The apparatus will be marked with this symbol when it is important that the user refers to the associated warning statements given in the User's Guide.

Warnings

- Switch off all equipment before connecting or disconnecting their digital interface. Failure to do so could damage the equipment.
- Whenever it likely that the correct function or operating safety of the apparatus has been impaired, the apparatus must be made inoperative and be secured against unintended operation.
- Any adjustment, maintenance and repair of the open apparatus under voltage must be avoided as far as possible and, if unavoidable, must be carried out only by trained service personnel.

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Chapter 1

Introduction

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1.1 About this Volume

This volume describes the programming and operation of the serial and parallel interfaces of the Type 2144 Analyzer. It is intended as a reference guide for IEEE 488/RS–232–C programmers and users. It is assumed that users are familiar with manual operation of the analyzer, described in Volume 1 of this User Guide, and have some experience of interface programming.

1.2 Summary of Contents

The following chapters describe the operation of the 2144 IEEE–488/RS–232–C interfaces.

Chapter 2 describes the specifications and the setup proceedure for the IEEE–488 interface, while Chapter 3 gives a similar description of the RS–232–C interface. Chapter 4 describes the interface message formats and some features common to both interfaces. Chapters 5, 6, 7 and 8 describe how the individual messages are used in the control of data flow between the 2144 and an interface controller. Chapter 9 lists the interface error messages, while Chapter 10 describes data formats for transfer over the IEEE–488/RS–232–C interfaces and storage in disk files. Chapter 11 is the index.

Chapter 2

The IEEE–488 Interface

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2.1 Interface Specifications

2.1.1 Interface Functions Implemented

The interface of the 2144 implements the following functions as specified in IEEE Std 488–1978 — "IEEE Standard Digital Interface for Programmable Instrumentation". The sections referred to are the relevant sections of the IEEE standard. The equivalent clauses of IEC Publication 625–1 are given in parentheses.

Section 2,3	Source Handshake (SH) Interface Function (Clause 6) SH 1—complete capability
Section 2,4	Acceptor Handshake (AH) Interface Function (Clause 7) AH 1—complete capability
Section 2,5	Talker (T) Interface Function (Clause 8) T 5—complete capability
Section 2,6	Listener (L) Interface Function (Clause 9) L 3—complete capability
Section 2,7	Service Request (SR) Interface Function (Clause 10) SR 1—complete capability
Section 2,8	Remote Local (RL) Interface Function (Clause 11) RL 1—complete capability
Section 2,9	Parallel Poll (PP) Interface Function (Clause 12) PP 1—remote configuration
Section 2,10	Device Clear (DC) Interface Function (Clause 13) DC 1—complete capability
Section 2,11	Device Trigger (DT) Interface Function (Clause 14) DT 1—complete capability
	All other functions—no capability

For further details of the above functions refer to the relevant sections of the IEEE or IEC standards.

2.1.2 Interface Connections

Up to 15 devices can be interconnected in an IEEE–488 bus system.

The maximum permitted cable length of the bus is 2 metres (6 ft) × the number of instruments in the system, up to a 20 metre (60 ft) maximum. Also, it is recommended that cable lengths between individual instruments connected to the bus be no greater than 4 metres (12 ft).

The IEEE interface connector of the 2144 is a 24-way female "micro-ribbon" connector, as specified in IEEE Std 488. The analyzer can be connected to other instruments fitted with this type of connector using the 2 m long Brüel & Kjær IEEE Interface Cable, AO 0265. Cable AO 0265 has screw-locking stackable connectors, allowing a number of connections to be made at the same point during system interconnection.

Brüel & Kjær also supply cables and adaptors for interface bus connections to instruments fitted with the older IEC-625 standard connector (Brüel & Kjær part nos. AO 0264 and AO 0195).

2.1.3 Interface Addresses

Each device in an IEEE interface bus system has at least one listener and/or talker address depending on its function. When an interface controller contacts a device over the interface, it sends a device address which contains the appropriate talker or listener address. This address is in ASCII (ISO 7-bit) code; bit 8 is not used for addressing and is ignored.

The 2144 analyzer uses one interface bus address. On delivery, the address is set to the factory default value 15 (decimal). If you wish to change the device address, see section 2.3 for details.

2.1.4 Interface Management Lines

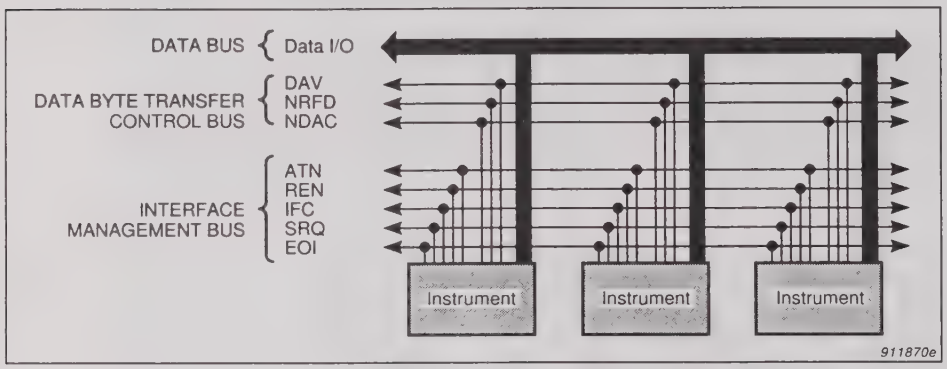

Fig. 2.1 Overview of the IEEE bus lines

The REN Line

The interface REN or Remote ENable line is used in conjunction with other signals to select between manual operation via the front panel controls of the analyzer and remote operation via the interface bus. The REN line is controlled by the device currently specified as the system controller. Most system controllers set the REN line to its "true" state immediately on taking control of the bus. For further details of how this function is implemented in the 2144, see sections 2.5 and 7.12.

The IFC Line

The Interface Clear line resets the interface circuitry to a known operational state. This IFC line is used by the System Controller to place talkers and listeners in an unaddressed state.

The SRQ Line

A service request is generated by setting the interface Service Request (SRQ) line. For details of the service request system of the 2144, see section 7.1.

The EOI Line

The End Or Identify (EOI) line is used to indicate the last byte of a data transfer over the bus, or to initiate a parallel polling sequence, when used in combination with the Attention (ATN) line. The ana-

lyzer terminates all data transfer sent over the bus by setting the EOI line simultaneously with the transmission of the last Data Byte (DAB) of a message.

Note:

When the analyzer senses the EOI line set during reception of a data byte (DAB), reception is terminated.

2.2 How to Activate the IEEE Interface

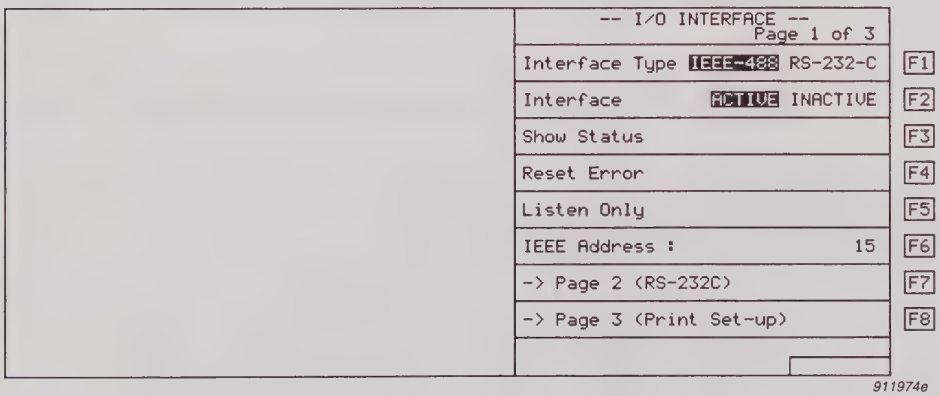

Fig. 2.2 I/O Interface menu, page 1

To activate the IEEE interface, after first switching the analyzer on, display page 1 of the I/O Interface menu (see Fig. 2.2), then:

1. Select `Interface INACTIVE`, using soft key **"F2"**.
2. Select `IEEE-488` in the `Interface Type` field, using soft key **"F1"**.
3. Select `Interface ACTIVE`, using soft key **"F2"**.

Note:

The I/O Interface parameters cannot be changed with the interface `ACTIVE`.

2.3 How to Select the Device Address

ASCII Address Characters		Address Code
Listen	Talk	
SP	@	0
!	A	1
"	B	2
#	C	3
$	D	4
%	E	5
&	F	6
'	G	7
(	H	8
)	I	9
*	J	10
+	K	11
,	L	12
–	M	13
.	N	14
/	O	15
0	P	16
1	Q	17
2	R	18
3	S	19
4	T	20
5	U	21
6	V	22
7	W	23
8	X	24
9	Y	25
:	Z	26
;	[	27
<	\	28
=	]	29
>	^	30

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Table 2.1 Address codes for various device address settings

You can set the 2144 IEEE device address using soft key **"F6"**, on page 1 of the I/O Interface menu and the numeric entry keys. The possible address settings are listed in Table 2.1. The factory default setting (decimal 15) is indicated by the shaded area.

2.4 Using the SRQ Key

When you press the **"SRQ"** key, the analyzer sends a Service Request if:

- The IEEE interface is set to ACTIVE in the I/O Interface menu, and
- This function is enabled in the SRQ mask (see section 6.1).

The **SRQ** LED indicates that the analyzer is waiting to be serviced by the controller. It is lit when one or more of the conditions defined in the SRQ mask are satisfied. It is switched off again when the controller carries out a serial poll on the analyzer. For details of the 2144 Service Request system, see section 7.1.

2.5 Local and Remote States

When a controller addresses the analyzer as a LISTENER, it can put the analyzer into the **Remote** state. It does this if the REN (Remote Enable) line was set to TRUE prior to the addressing. When this happens the **Remote** LED is lit and the normal operation of the front panel keys is inhibited. When the analyzer is in **Remote** mode, all the analyzer keys are inoperative, with the exception of: **"Local"**, **"Reset"**, **"Power On/Off"**, **"Viewing Angle"**, **"X-axis Scroll"**, **"Y-axis Scroll"**, **"SRQ"** and **"Display Backlighting On/Off"** (back panel).

The analyzer returns to **Local** mode when:

- The **"Local"** key is pressed, or
- The REN line is (re)set to FALSE

The **Remote** LED is then switched off, and all the manual keys work normally again.

Notes:

- If the controller, using the bus command LLO (local lockout), has put the analyzer into the LOCAL LOCKOUT mode, then the **"Local"** key has no effect. In this case the controller, using the bus command GTL, can put the 2144 into the LOCAL WITH LOCKOUT mode. In this mode the front panel operates normally.

- The RS–232–C has no REN line, and the bus command LLO cannot be used. In this case the **Remote/Local** function is implemented using the messages **REM**ote and **LoCK**out. See section 7.12 for further details.

2.6 Listening and Talking

The **Listen** LED lights when the analyzer is addressed as a **Listener**. It happens when:

- The analyzer is addressed by a controller, or
- Soft Key **"F5"**, `Listen only`, on page 1 of the I/O interface menu is pressed.

The **Listen** LED is switched off again when the 2144 is unaddressed. This can occur in several different ways:

- A controller sets the IFC (interface clear) bus line.
- Unaddress is received from a controller (address 31).
- The analyzer is addressed as a **Talker**.
- The **"Hard Copy"** key is pressed a second time (see section 4.3).
- The interface is made `INACTIVE`.
- The soft key **"F5"** is pressed a second time.

The **Talk** LED lights when the 2144 is addressed as a **Talker**. It happens when:

- The analyzer is addressed by a controller, or
- When a printout is started by using the **"Hard Copy"** key.

The **Talk** LED is switched off again when the 2144 is unaddressed. This can occur in several different ways:

- A controller sets IFC.
- Another talk address is received from a controller.
- The analyzer is addressed as a **Listener**.
- The **"Hard Copy"** key is pressed for a second time.
- The interface is made `INACTIVE`.

Note:

The Listen and Talk functions are used differently with the RS–232–C interface. This is described in sections 3.3 and 7.12.

2.7 IEEE–488 Reset Levels

The interface has three levels of reset. The controller resets the interface by sending one of the following messages:

- **Interface Clear (IFC)** - All devices connected to the bus are unaddressed.
- **Device Clear (DCL) or Selected Device Clear (SDC)** - Parsing is restarted and interface errors are cleared.
- **RES**et - This has the same effect as a manual reset.

Note:

Parsing is the compiler operation of identifying the elements of instructions in terms of the programming language.

Chapter 3

The RS–232–C Interface

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3.4 RS–232–C Reset Levels 3–11

3.1 Hardware/Functional Specifications

This section describes the physical level of the interface. The serial interface of the 2144 conforms to EIA standard RS–232–C, which is equivalent to the CCITT V.24 recommendation.

The interface of the 2144 is coupled as "Data Terminal Equipment" (DTE), and it operates in full duplex mode, which means that the interface is capable of operating in both directions simultaneously.

3.1.1 RS–232–C Interface Connector

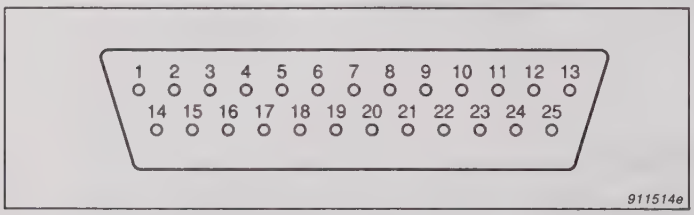

Fig. 3.1 The RS–232–C interface connector of the 2144.

The interface connector is a 25-pin D-range male connector. It is located on the rear panel of the 2144, see Volume 1 of this User's Guide (section 3.2) for details. Fig. 3.1 shows the numbering of the pins on the connector. Pin definitions are given in Table 3.1.

Pin No.	RS–232–C	CCITT V.24	Description	Mnemomic	Direction
1	AA	101	Protective Ground	P GND	—
2	BA	103	Transmitted Data	TxD	From 2144
3	BB	104	Received Data	RxD	To 2144
4	CA	105	Request to Send	RTS	From 2144
5	CB	106	Clear to Send	CTS	To 2144
6	CC	107	Data Set Ready	DSR	To 2144
7	AB	102	Signal Ground	S GND	—
8	CF	109	Data Carrier Detect	DCD	To 2144
20	CD	108.2	Data Terminal Ready	DTR	From 2144

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Table 3.1 Pin definitions for the RS–232–C interface

3.1.2 Data Lines

Pins 2 and 3, Transmitted Data and Received Data, are data lines. For data lines, RS–232–C specifies that:

- A voltage below –3 V signifies a binary 1
- A voltage above +3 V signifies a binary 0
- When a data line is passive, it is held in the binary 1 condition.

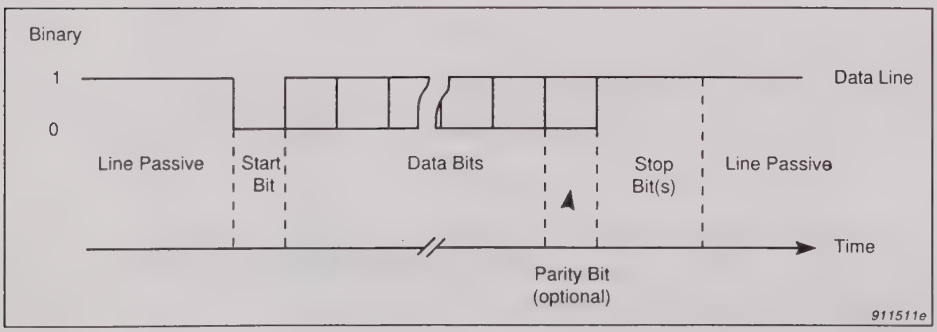

Fig. 3.2 Asynchronous transmission of 1 byte of data

Data transmission is asynchronous as illustrated in Fig. 3.2.

3.1.3 Control Lines

Pins 4, 5, 6, 8 and 20 are the connections for the control lines. For control lines, the RS–232–C standard specifies that:

- A voltage above +3 V signifies the on state
- A voltage below –3 V signifies the off state.

The use of the control lines is described further in section 3.2.6.

3.1.4 Cables

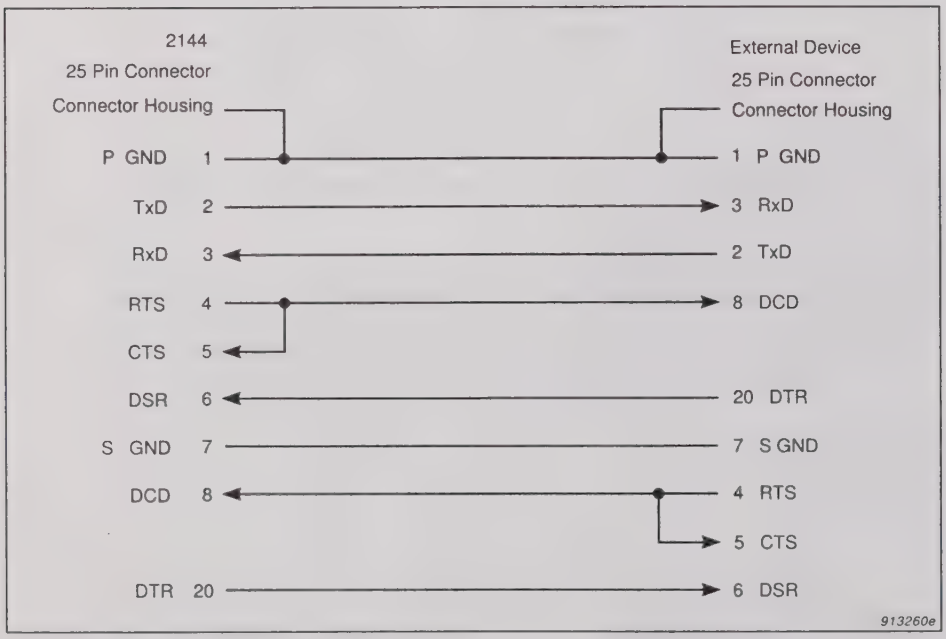

Fig. 3.3 Null-modem cable with 25-pin connectors at both ends (Brüel & Kjær order numbers WL 0946 and WL 0947)

A null-modem cable must be used to interface the 2144 to another DTE-coupled device (computer or printer). Fig. 3.3 shows the connections of a null-modem cable with 25-pin connectors at both ends. Fig. 3.4 shows the connections of a null-modem cable equipped with a 25-pin connector at one end and a 9-pin connector at the other end.

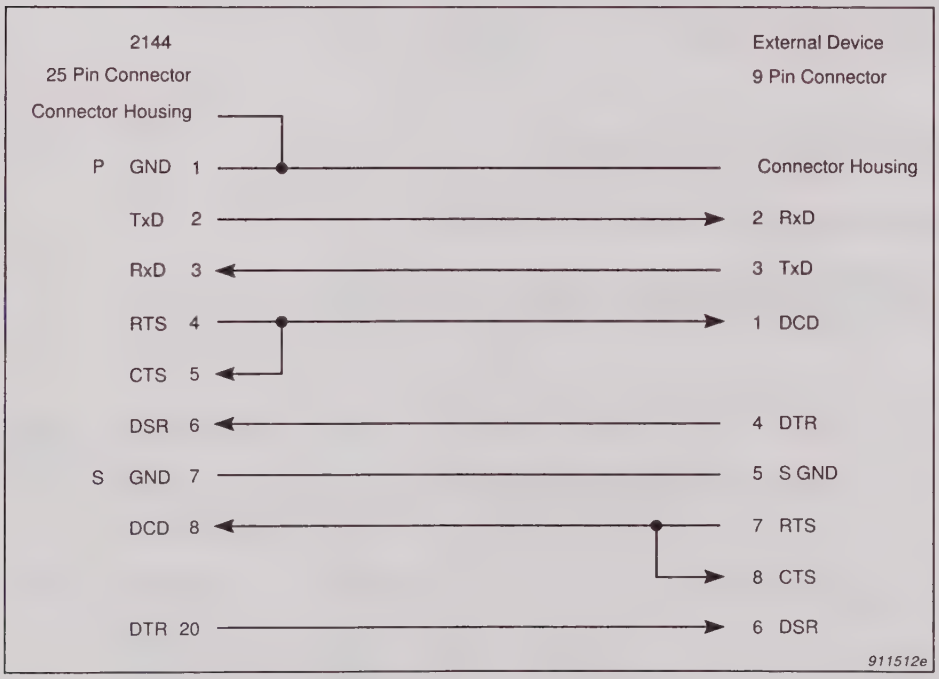

Fig. 3.4 Null-modem cable with one 25-pin connector and one 9-pin connector (Brüel & Kjær order number WL 0945)

Interface cables can be ordered from Brüel & Kjær. Table 3.2 shows order numbers and usage of cables.

Order No.	Connectors	Used to Interface to
WL 0945	25 pin female 9 pin female	Computer or printer with 9 pin male RS–232–C connector
WL 0946	25 pin female 25 pin female	Computer or printer with 25 pin male RS–232–C connector
WL 0947	25 pin female 25 pin male	Computer or printer with 25 pin female RS–232–C connector

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Table 3.2 Brüel & Kjær RS–232–C null-modem cables

3.2 RS–232–C Interface Setup

3.2.1 How to Activate the RS–232–C Interface

To activate the RS–232–C interface, after first switching the analyzer on, display Page 1 of the I/O Interface Menu (see section 3.1), then:

1. Select `Interface INACTIVE`, using soft key **"F2"**.
2. Select `RS-232-C` in the `Interface Type` field, using soft key **"F1"**.
3. Select `Interface ACTIVE`, using soft key **"F2"**.

Note:

The I/O Interface parameters cannot be changed with the interface `ACTIVE`.

To set up the RS–232–C interface, first select page 2 of the menu (using soft key**"F7"**).

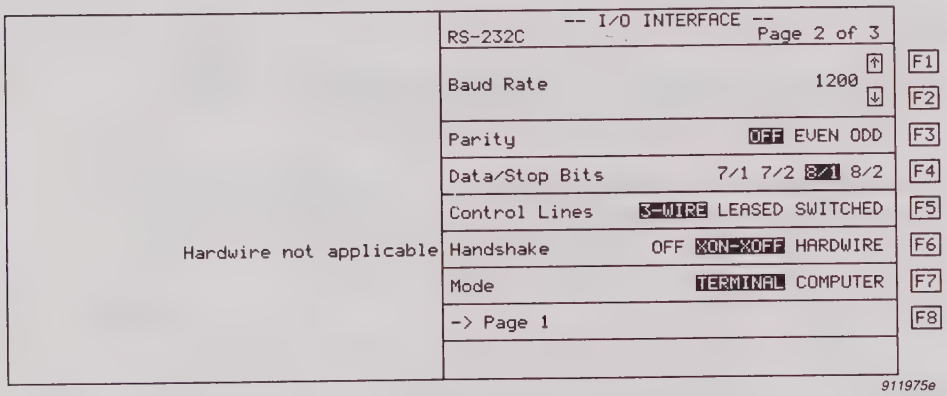

Fig. 3.5 Page 2 of the I/O Interface menu (RS–232–C)

To change the interface setup parameters, use soft keys **"F1"** to **"F7"**. Soft key **"F8"** is used to return to page 1 of the I/O Interface menu. The setup parameters are described in sections 3.2.2 to 3.2.7.

3.2.2 Baudrate

The baudrate is the speed of data transmission. The baudrate options are 300, 600, 1200, 2400, 4800 and 9600 bits/second.

3.2.3 Parity

Checking the parity of a transmitted byte is a means of detecting transmission errors. Even (odd) parity means that a transmitted byte must contain an even (odd) number of binary 1's. To achieve this, one extra bit — the parity bit — is added to each byte transmitted. When **None** is selected, no parity check is performed.

You can select from the following options:

- Even
- Odd
- None.

3.2.4 Data/Stop Bits

The number of data bits determines how many bits are transmitted for each character. You can select 7 or 8 data bits to a character.

Note: You must use 8 data bits to transmit block data.

The number of stop bits determines for how long the data line must be in the passive state before the transmission of a new byte can begin. The 2144 can use 1 or 2 stop bits.

3.2.5 Handshaking

Handshaking is the method used by the 2144 and the external device to synchronize their transmissions. You can select one of three options:

- X-On/X-Off handshake
- Hardwired handshake
- None.

When X-On/X-Off handshake is used, the 2144 transmits the X-Off character (ASCII 19) when it can handle no more input data. When the 2144 is once again ready to receive data, it transmits the X-On character (ASCII 17) over the interface. Similarly, when the 2144 receives an X-Off character during a transmission, it stops transmitting until it receives the X-On character.

In hardwired handshake mode, the 2144 sets the DTR control line (pin 20) off when it will accept no more data. When it is ready to receive more data, the DTR line is set on. When the external device sets the DSR control line (pin 6 of the 2144) off, the 2144 stops transmitting until DSR goes back on.

If `None` is selected, handshaking is disabled.

3.2.6 Control Lines

This parameter determines how the 2144 uses the control lines of the interface. There are three options:

- 3-Wire
- Switched
- Leased.

3-Wire

In 3-wire mode, only the data lines are used. All control lines are ignored. This means that the only handshake method available is X-On/X-Off.

Switched

In switched line mode, the CTS and DSR control lines are monitored. If one of the two control lines is set to off, data transmission from the analyzer is blocked. It is recommended that the external device uses the DSR line for handshaking.

Leased

In leased line mode, the CTS, DSR and DCD control lines are monitored. CTS and DSR have the same effect as in switched line mode. If the DCD input control line goes off, the 2144 ignores all incoming data.

3.2.7 Terminal and Computer Modes

The COMPUTER or TERMINAL modes may be selected using soft key **"F7"**, on page 2 of the I/O Interface menu.

Terminal Mode

In this mode, which is intended for use with a "dumb" terminal, every printable character is echoed as soon as it is received. A prompt is transmitted whenever the analyzer is ready to receive a new message.

This prompt is: "< CR >< LF >$"

There is also a simple screen editor.

Example:

When the RS–232–C interface is activated, the prompt is sent, and the terminal screen shows:

```
$■
```

After executing the message "S_R_E? <CR><LF>", the screen shows.

```
$ S_R_E?
S_R_E 0

$■
```

Editing Functions

In Terminal mode, the analyzer stores input data (characters) in its input buffer. When the buffer is full (132 characters), or when a <LF> is received, the buffer contents are processed and the buffer is cleared. The buffer can also be cleared manually.

The last character received in the buffer can be deleted by sending <BS> or <DEL> to the analyzer. When this happens the cursor on the terminal screen moves one space to the left, but does not delete the character on the screen. This can be repeated as many times as there are characters in the buffer.

Notes:

- If a character string is typed in which is so long that it runs onto a new line, then the cursor cannot be moved back to the previous line by using <BS>. However, a character is still deleted in the input buffer for each subsequent keystroke.

- Entering block data in terminal mode is not recommended. However it is possible, provided that the data does not contain <LF>, <BS> or <DEL> and the total length of the input string < 132 characters.

Computer Mode

In this mode the analyzer is connected to an intelligent controller. Neither echo nor prompt are transmitted and it is not possible to edit transmitted data.

3.3 Listening and Talking

The **Listen** LED lights when the analyzer is receiving data over the interface i.e. it is addressed as a "listener". It is turned on when the first character of a message header is received, and is switched off when:

- The analyzer begins to send a response message, or
- The interface is made INACTIVE.

The **Talk** LED lights when the analyzer is sending a response message via the bus i.e. when the analyzer is functioning as a "talker". This occurs when:

- A query message has been received from the controller, and the analyzer starts to transmit a response message, or
- A printout is started using the **"Hard Copy"** key.

The **Talk** LED is switched off again when:

- The response-message transmission/printout is completed, or
- The **"Hard Copy"** key is pressed a second time, or
- The interface is made INACTIVE

3.4 RS–232–C Interface Reset Levels

The RS–232–C Interface has two levels of reset:

- Sending a <Break> to the analyzer via the RS–232–C interface will restart parsing.
- Sending a **RES**et message to the analyzer has the same effect as a manual Reset (see section 5.1).

4.1 Formats for Interface Messages

4.1.1 Terminology for Interface Messages

The data transmitted to and from the Type 2144 analyzer conforms to a subset of the ANSI/IEEE Standard, IEEE 488.2 (1987), "IEEE Standard Codes, Formats, Protocols and Common Commands".

Both the IEEE and RS–232–C interfaces are used to transfer data to and from the analyzer. This transferred data is referred to as a "message". Two types of message can be sent to the analyzer, "command" and "query" messages. Messages output by the analyzer replying to a query message from a controller are referred to as "response" messages.

Messages to the Analyzer

All messages sent to the analyzer start with a "header". A header consists of one or more "words". The simplest messages are made up of a single word header,

e.g. `HOLD`

If a header requires more than one word, the words are joined by "word concatenators". The underline character (_) is used as the word concatenator.

e.g.
```
RESET_STATUS_BYTE
SERVICE_REQUEST_ENABLE?
```

Headers that end with a question mark (query messages) will cause the analyzer to output data (response message). Headers without question marks (command messages) are used to set up the analyzer or input data to the analyzer.

Headers may be followed by one or more data fields. The header is separated from the data fields by a "header separator" which is a space (SP). Data fields that consist of more than one word are joined by word concatenators.

e.g. `AVERAGING LIN_AVG_TIME,5M`
`MEASUREMENT_TYPE ONE_CHANNEL`

A single header can be used to define a number of data fields in the analyzer. If the message contains several data fields, then the data fields are separated by a "data separator", which is always a comma.

e.g. `HOLD TYPE,MAX,MODE,INACTIVE,1`

Several messages can be sent together, joined by a message separator, which is a semi-colon (;).

e.g. `ERROR_STOP YES;UPDATE UPDATE_MEAS`

Messages from the Analyzer

The structure of the response messages returned by the analyzer depends on the nature of the query from the controller. The messages will be in minimum code (mnemonics) see section 4.1.4.

4.1.2 Use of Syntax Diagrams

In this manual syntax diagrams are used to explain the individual messages. Syntax diagrams use three types of symbols, refer to Fig. 4.1.

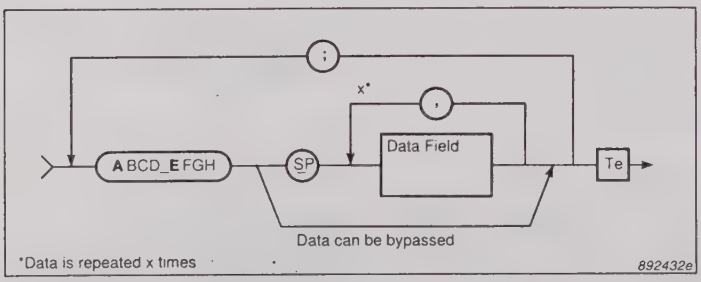

Fig. 4.1 General message syntax

Rectangular symbols indicate that the enclosed data must be replaced by a data item defined elsewhere or chosen by the user. The name of the data item is quoted in the upper left-hand corner of the

symbol. The type of the data item and its allowed length in parenthesis, are given in the lower right-hand corner. Circular symbols enclose single character literal data that must be included in the message. Elongated, round ended symbols indicate literal word data. These round ended symbols are usually used to illustrate message headers.

Data items that may be by-passed, are indicated by angled lines to and from the main flow line. Data items that **may** be repeated, are indicated by lines that loop vertically from the main flow line back over the data item and back to the main flow line. If an item of data **is** repeated, then the number of repetitions is indicated by a number above the flowline. Flow is from left to right unless arrows indicate otherwise.

Note:

For the 2144, all setup message commands (described in Chapter 6) change the display to the menu containing the data fields used in that particular message. If only the header is sent and the data fields are bypassed (see Fig. 4.1), then the analyzer displays the first page of the relevant menu.

4.1.3 General Rules for Constructing an Interface Message

The 2144 allows you to input the message headers and any character type data fields in full. For ease of use, the data field names used correspond to those used on the analyzer's front panel pushkeys and screen texts wherever possible.

In order to reduce coding and transmission time, mnemonics for each of the message components which use character type data can be entered. The mnemonics are derived from the names of the individual headers or data fields. The general syntax of these mnemonics is the same for headers and character type data fields. Throughout this manual a message's minimum allowable mnemonic is given in bold upper case text. In addition, the following rules apply:

1. All entries can always be written out in full. For example,

```
DISPLAY_MODE  MODE_OPTIONS,DUAL
```

2. Both upper and lower case letters are recognized and are equivalent.

```
DISPLAY_MODE   MODE_OPTIONS,DUAL
display_mode   mode_options,dual
dIsPlay_MODe   mODe_oPtiONs,dUAl
```

3. All headers and character type data fields can be truncated down to the mnemonic.

```
DISPLAY_MODE   MODE_OPTIONS,DUAL
    DISP_MOD   MOD_OPT,DUA
         D_M   M_O,DU
```

4. All mnemonics are unique and consist of from one or more words, with each word consisting of one to three characters, plus the word concatenators.

5. The character type data parts of messages received by the analyzer are checked only with the mnemonic. Therefore, any misspelled words are undetected, provided that the mnemonics are correctly entered.

6. The analyzer returns only the mnemonics when transmitting data containing headers and character type data fields over the bus.

7. Between the header and the first data field, a header separator is entered. The header separator is a space (SP).

8. Between each of the data fields, the data separator (a comma <,>) must be entered. See section 4.1.1.

10. Some headers allow data to be both sent to and requested from the analyzer (commands and queries). Where this is the case, you can convert a command header into a query by appending a "?".

Command message:	Query Message:
D_MM 0,DU	D_M?

4.1.4 Mnemonic Codes

The following general rules apply to help you understand the construction of the mnemonics (minimum codes). The rules apply for all headers and data fields which use character type data.

1. If taking the first letter of every word gives a unique code, then this is the mnemonic. For example, the header

   SERVICE_REQUEST_ENABLE becomes S_R_E
   MEASUREMENT_TYPE becomes M_T

2. If the first letter of every word does not give a unique mnemonic, then include two or more characters of one or more words until the mnemonic is unique. For example, the message

   AVERAGING_CONTROL START becomes A_C STA
   AVERAGING_CONTROL STOP becomes A_C STO

Notes:

- Word concatenators are always required in mnemonics which include more than one word, except immediately before the question mark (?) in an input message header. Here, the inclusion of the word concatenator is optional.

- Only the minimum code is recognized internally. In the tables and syntax diagrams throughout this interface manual, the mnemonics are the characters appearing in bold within the headers and character type data fields.

- Headers are always output in mnemonic form by the analyzer.

4.1.5 Message Terminators

Note:

The following rules for the use of message terminators, including the EOI line, only apply to the IEEE–488 interface. The EOI line is not available with RS–232–C.

The message terminator is the last byte transmitted **at the end of an IEEE message** to signify the end of the transmitted data. Fig. 4.2 lists the possible terminators.

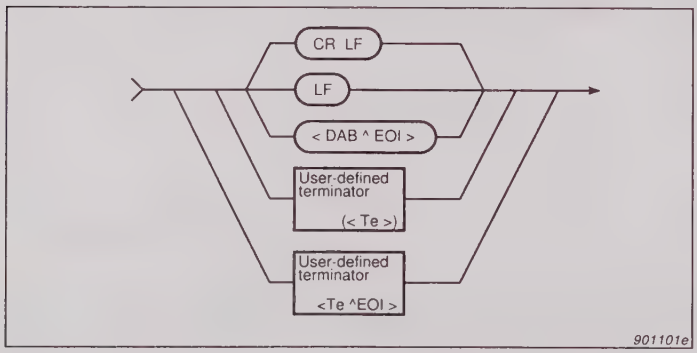

Fig. 4.2 Syntax for valid message terminators

By default, the line feed character (LF) is defined as the terminator and is transmitted from the analyzer simultaneously with the End Or Identify line (EOI). This terminator can be redefined to any ASCII character decimal value between 1 and 31, with the exception of 13. These available user-defined terminators are given in Table 4.1. Throughout this manual the user definable message terminator is referred to as "Te".

Bit Numbers b_4 b_3 b_2 b_1	b_7 b_6 b_5 0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
0 0 0 0	NUL	DLE	SP	0	@	P	‘	p
0 0 0 1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0	STX	DC2	“	2	B	R	b	r
0 0 1 1	ETX	DC3*	#	3	C	S	c	s
0 1 0 0	EOT	DC4	$	4	D	T	d	t
0 1 0 1	ENQ	NAK	%	5	E	U	e	u
0 1 1 0	ACK	SYN	&	6	F	V	f	v
0 1 1 1	BEL	ETB	’	7	G	W	g	w
1 0 0 0	BS	CAN	(	8	H	X	h	x
1 0 0 1	HT	EM	)	9	I	Y	i	y
1 0 1 0	LF	SUB	*	:	J	Z	j	z
1 0 1 1	VT	ESC	+	;	K	[	k	{
1 1 0 0	FF	FS	,	<	L	\	l	¦
1 1 0 1	CR	GS	–	=	M	]	m	}
1 1 1 0	SO	RS	.	>	N	‾	n	~
1 1 1 1	SI	US	/	?	O	_	o	DEL

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* see note below

Table 4.1 List of allowed user–defined message terminators (Te)

You can set the terminator using the message "Define_Terminator" (see section 7.2). The highlighted text below offers examples of valid terminators.

```
RESET_STATUS_BYTE<Te>
RESET_STATUS_BYTECR LF
RESET_STATUS_BYTELF
RESET_STATUS_BYTE<LF∧EOI>
RESET_STATUS_BYT<E∧EOI>
```

When information is output from the analyzer, the user-defined terminator (Te) will always be sent simultaneously with the EOI line. Data output from the analyzer is transmitted as in the following example.

```
S_R_E 129<Te∧EOI>
```

4.2 Types of Data

A message can contain one or more data fields, or none. The type of allowed data varies for each individual message, but the available types are:

- character data
- numeric data
- string data
- block data

The data separator used between all data fields is a comma (,). See Fig. 4.3 for the general syntax of a message containing all legal data types.

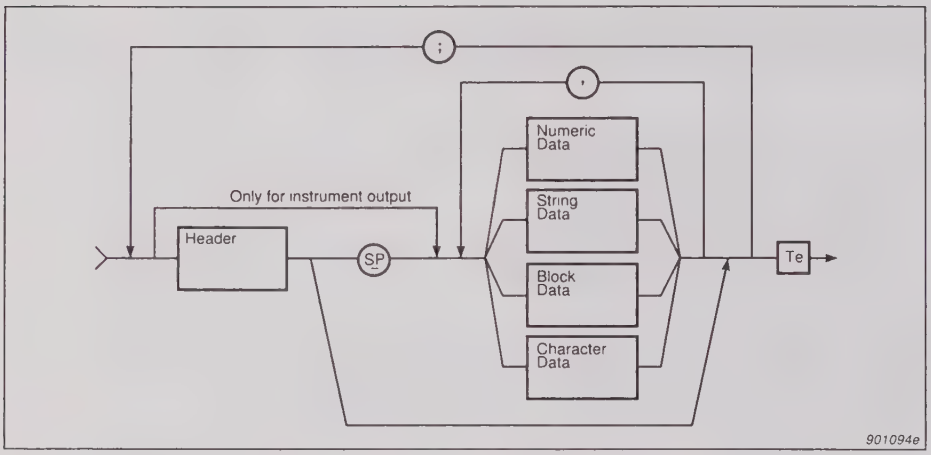

Fig. 4.3. General format for a message with all legal data types

4.2.1 Character Data

Character data must begin with an alphabetic character, either upper or lower case. This initial alphabetic character can be followed by any printable ASCII character, with the exception of a space (SP), a comma (,), a semi-colon (;), or the delete character (DEL). The valid ASCII characters are 33 through 126 (Decimal), with the exception of 44 (Decimal), and 59 (Decimal). Fig. 4.4 shows the valid form of entry for character data.

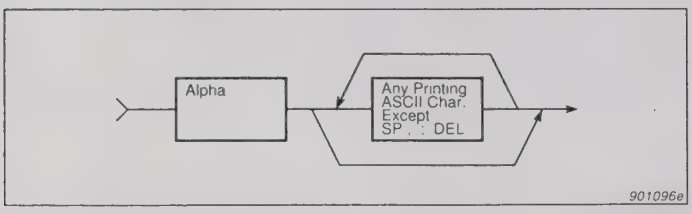

Fig. 4.4 General syntax for character data fields

All headers and most setup field names are character data, as are many of the setup field settings. In the syntax diagrams, character

data is represented by "Char.". When character data **must** be included , the data is written out in full in the syntax diagrams.

4.2.2 Numeric Data

Numerical data that is entered through the interface closely follows the format defined in the ANSI/IEEE 488.2 - 1987 Standard, "IEEE Standard Codes, Formats, Protocols and Common Commands" and the ISO 6093 - 1985 Standard, "Representation of numerical values in character strings for information interchange". The types of numeric data are represented in the syntax diagrams by NR1, NR2 and NR3, conforming to the above mentioned standards. The data is checked for illegal numbers not conforming to the above standards. The analyzer accepts in most cases the full NR3 (explicit point scaled representation, see Fig. 4.8), except where syntax diagrams state that NR1 or NR2 is required. The syntax for numerical entry, NR1. NR2 and NR3, is shown in Figs. 4.5, 4.6, 4.7 and 4.8.

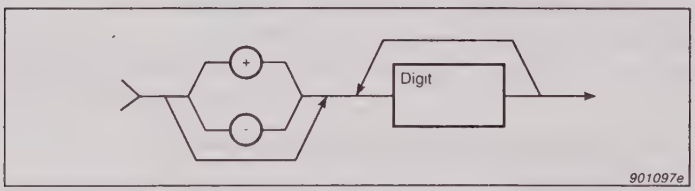

Fig. 4.5 Syntax for numerical data of type NR1 (implicit point representation)

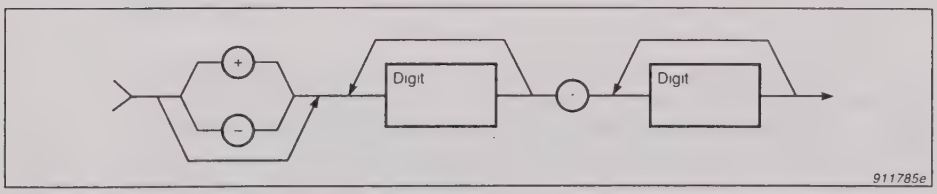

Fig. 4.6 Syntax for numerical data of type NR2 (explicit point scaled representation without exponent)

A digit is any of the 10 number symbols, 0 through 9.

The following suffixes are available for entry through the interface.

k	or	K	representing	kilo	and equivalent to	E+3
m	or	M	representing	milli	and equivalent to	E-3
u	or	U	representing	micro	and equivalent to	E-6

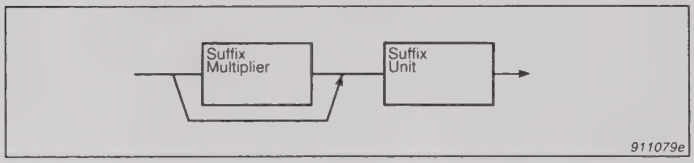

Fig. 4.7 Syntax for suffixes

When information containing any of these non-numeric suffixes is output from the analyzer, it is expressed in exponential notation. The analyzer writes out certain numerical values in a fixed format for easier interpretation in the controller. This depends on which message is used. In the following text, most messages to be output from the analyzer are illustrated with examples or syntax diagrams.

Note:

The maximum number of significant digits recognised by the analyzer is 29 (including exponent).

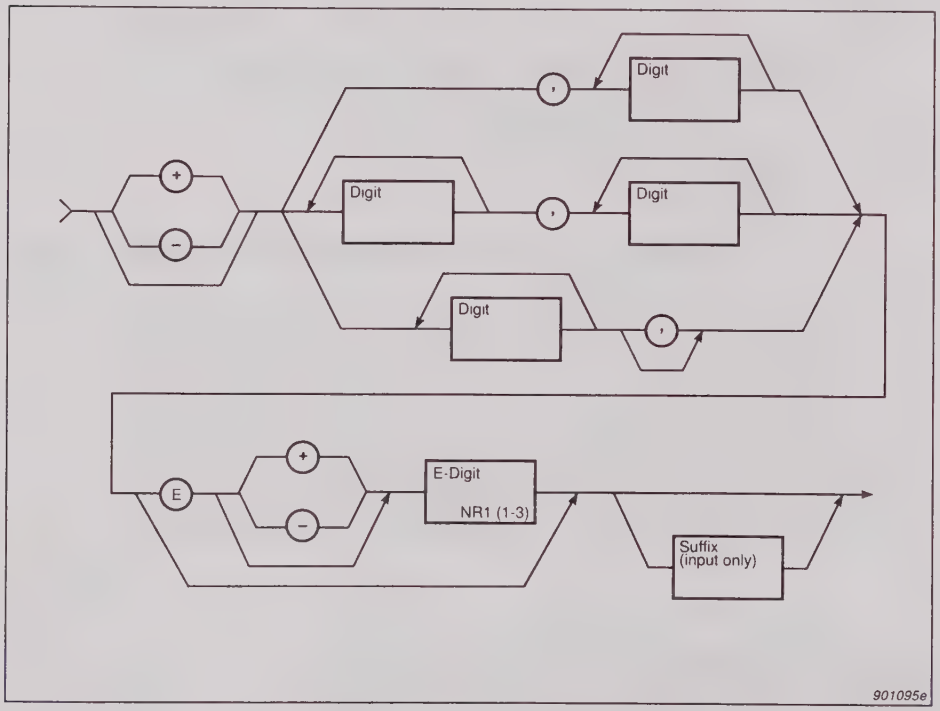

Fig. 4.8 Syntax for numerical data of type NR3 (explicit point scaled representation with exponent)

4.2.3 String Data

String data is the format used to enter a text in a message. In addition, it is used to enter special characters not allowed in character data fields.

String data is always enclosed in quotation marks. To include one quotation mark in the string data field, two quotation marks need to be entered. Fig. 4.9 gives the syntax for entering string data. The length in characters of a fixed length string data is given in parenthesis after the data type name.

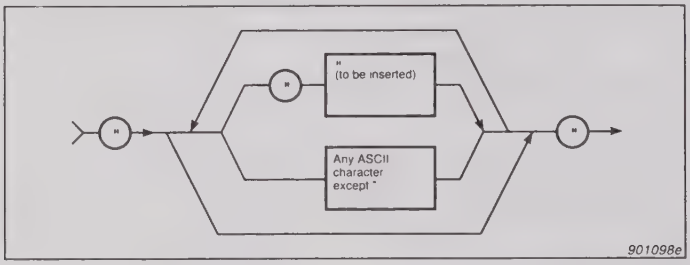

Fig. 4.9 Syntax for entering string data

Example:

```
"This is the text."
"This text contains "" one quotation mark."
```

4.2.4 Block Data

This describes the way block data is transmitted over the bus by the analyzer. The block data fields conform to the general format for "definate length arbitrary block data" as defined by IEEE Standard 488.2 – 1987. See Fig. 4.10 for the syntax of block data.

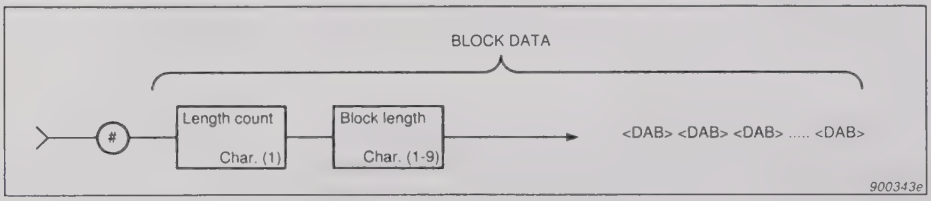

Fig. 4.10 Syntax for valid entry of block data

The length count gives the number of characters in the block length field. The length count is a number in the range 1 to 9. The block length gives the number of data bytes (<DAB>) in ASCII form found after the block length field (See section 7.14).

Example:

#3158 <DAB> <DAB> <DAB> . . . <DAB>

158 bytes

4.3 How to Make a Hard Copy

You can print out the information on the analyzer screen on a connected printer using the **"Hard Copy"** key on the analyzer front panel. Before printing you must select the correct print format for your printer, on page 3 of the I/O Interface menu (see Fig. 4.11). Press **"Hard Copy"** to print out a true raster copy of the analyzer screen. In Measurement Mode, there are three options for printing out your measurement data. You can select either GRAPHIC, GRAPHIC&TABLE, or TABLE, on page 3 the I/O Interface menu.

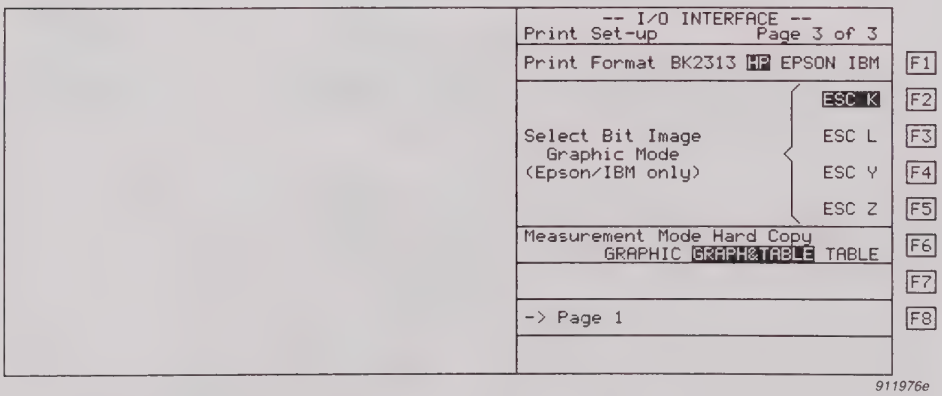

Fig. 4.11. Page 3 of I/O interface menu

Notes:

- If you select GRAPHIC, the readout is a true raster copy of the current analyzer screen, see Fig. 4.12.
- If you select TABLE, the screen information is output in tabular form, see Fig. 4.13.
- If you select GRAPHIC&TABLE, the printout includes both of the other two options.

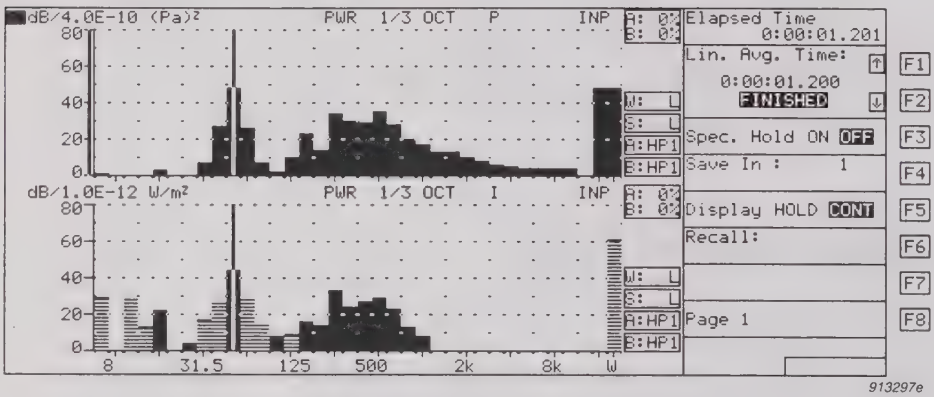

Fig. 4.12. Printout of measured data with the GRAPHIC option selected

When **"Hard Copy"** is pressed the analyzer goes into talk mode, and lights the **"Hard Copy"** and **"Talk"** LEDs (Unless the **"Hard Copy"** LED is already lit, or the analyzer is addressed over the interface).

The data is then read out to the printer via the IEEE–488 interface (or the RS–232–C, depending on which of them is currently selected). If **"Hard Copy"** is pressed again while the LED is still lit, the readout is interrupted and the analyzer leaves talk mode.

When the readout is complete, or if it is interrupted, the **"Hard Copy"** and **"Talk"** LEDs are turned off. Pressing **"Hard Copy"** again after this starts a new readout.

---------- B&K TYPE 2144 ----------

COPY TIME 17-OCT-1991 19:22:28

FREQ. [Hz]	LEVEL [dB]	FREQ. [Hz]	LEVEL [dB]	FREQ. [Hz]	LEVEL [dB]
400.00m	29.8	16.00	2.6	630.00	27.8
500.00m	15.8	20.00	-255.9	800.00	20.4
630.00m	11.9	25.00	0.2	1.00k	16.9
800.00m	-4.4	31.50	6.7	1.25k	13.3
1.00	-4.4	40.00	26.7	1.60k	13.0
1.25	-255.9	50.00	47.7	2.00k	9.9
1.60	-255.9	63.00	26.2	2.50k	8.2
2.00	1.5	80.00	7.4	3.15k	6.0
2.50	-7.4	100.00	2.1	4.00k	4.9
3.15	-10.4	125.00	9.8	5.00k	3.9
4.00	-3.4	160.00	22.9	6.30k	3.7
5.00	-10.4	200.00	14.0	8.00k	4.4
6.30	1.3	250.00	34.2	10.00k	4.0
8.00	-3.4	315.00	30.0	A/L	48.4
10.00	-8.7	400.00	29.4	W	48.5
12.50	-1.1	500.00	34.8		

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Fig. 4.13. Printout of measured data with the TABLE option selected

Note:

- If the interface is INACTIVE when **"Hard Copy"** is pressed, then it is activated automatically, and de-activated again when the printout is completed.
- For options GRAPHIC&TABLE and TABLE it is the Upper/Lower selection which determines which set of spectrum values is printed out.
- The first and last table values are determined by the current selections of Highest/Lowest centre frequency in the Display Mode menu.

4.4 The Show Status Function

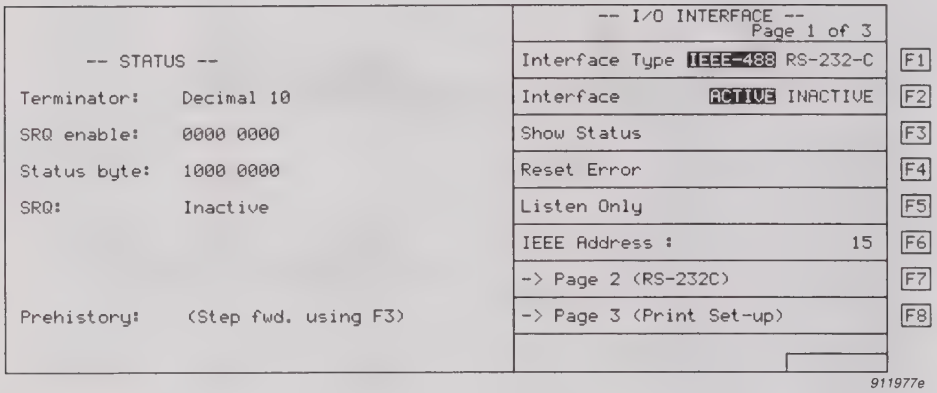

Fig. 4.14. Page 1 of I/O Interface menu after soft key F3 is pressed

Refer to Fig. 4.12.

Terminator: Shows the decimal value of the chosen terminator (default = 10 i.e. ASCII < LF >) See section 7.2 for the Define_Terminator message.

SRQ enable: Shows the current bit pattern for the status mask. See Service_Request_Enable, section 7.1.

Status byte: Shows the current bit pattern for the status byte.

SRQ: Can be either Active or Inactive.

Prehistory: Prehistory: (step forward using **"F3"**) is only displayed if **E**ror_**S**top **Y**es is chosen. See **E**rror_**S**top, section 7.3.

Chapter 5

Reset, Key Control and Boot/Load

5.1 RESet (RES) 5–2

5.2 Key_Control (K_C) 5–3

5.3 Boot and Load (B) and (L) 5–6

5.1 Reset (RES)

RESet (command only) is used to reset the analyzer via the interface. This has the same effect as manual resetting the analyzer, i.e. the interface is unaddressed and is placed in Local state. To reset the IEEE interface only, the IEEE **DCL** or **SDC** command is used. See sections 2.7 and 3.4.

Note:

This Reset can result in noise on the bus. The bus will be stable again after 10 secs.

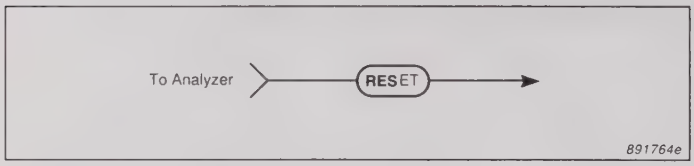

Fig. 5.1 Syntax for the RESet message

5.2 Key_Control (K_C)

The **K**ey_**C**ontrol command message is used to perform one of more of the "remote keystrokes" listed in Table 5.1. This has the same effect as pressing the corresponding key(s) on the front panel of the analyzer.

The query message, **K_C?**, returns a readout of the code for the last front-panel key operation, and the number of keys pressed since the last readout or reset (via the front panel or the bus).

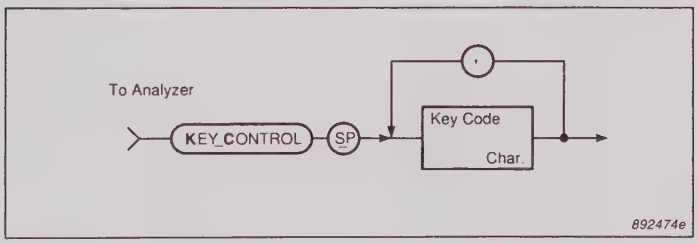

Fig. 5.2(a) Syntax for the K_C command message

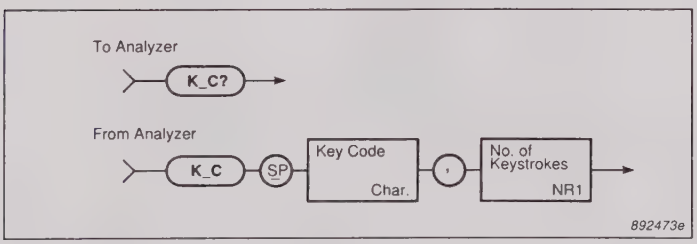

Fig. 5.2(b) Syntax for the K_C query message and analyzer response

Key Control Codes	
Key	**Code**
Main Menu	**MA_M**
Meas. Mode	**ME_M**
F1 to F8	**F1 to F8**
Next Menu	**N_M**
Prev. Page	**P_P**
0	**N0**
1	**N1**
2	**N2**
3	**N3**
4	**N4**
5	**N5**
6	**N6**
7	**N7**
8	**N8**
9	**N9**
.	**D_P**
Clear	**CL**
Recall	**REC**
k	**K**
m	**M**
+/–	**C_S**
Autoseq. Stop/Step	**A_S_S**
Trigger Manual	**T_M**
Averaging Mode Lin.	**A_M_L**
Averaging Mode Exp.	**A_M_E**
Averaging Start	**A_STA**
Averaging Proceed	**A_P**
Averaging Stop	**A_STO**

Table 5.1(a) K_C pushkeys and codes

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Key Control Codes	
Key	**Code**
Max. Input A Up	**M_I_A_U**
Max. Input A Down	**M_I_A_D**
Max. Input B Up	**M_I_B_U**
Max. Input B Down	**M_I_B_D**
Auto Range	**A_R**
Upper/Lower	**U_L**
Viewing Angle Up	**V_A_U**
Viewing Angle Down	**V_A_D**
Ampl. Scroll Up	**A_S_U**
Ampl. Scroll Down	**A_S_D**
Freq. Scroll Up	**F_S_U**
Freq. Scroll Down	**F_S_D**
Back Lighting On/Off	**B_L**
Hard Copy	**H_C**
SRQ	**SRQ**
Local	**L**
Reset	**RES**

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Table 5.1(b) K_C pushkeys and codes

5.3 Boot and Load

The **BOOT(?)** and **LOAD** messages used in combination provide an alternative method of loading a new program and re-starting the analyzer. They have the same effect as a manual bootload, described in Volume 1, section 4.1.2 of this User Guide. Before attempting to load a program, you should send the **BOOT?** query message (see Fig. 5.3(a)), to ensure that the analyzer is ready.

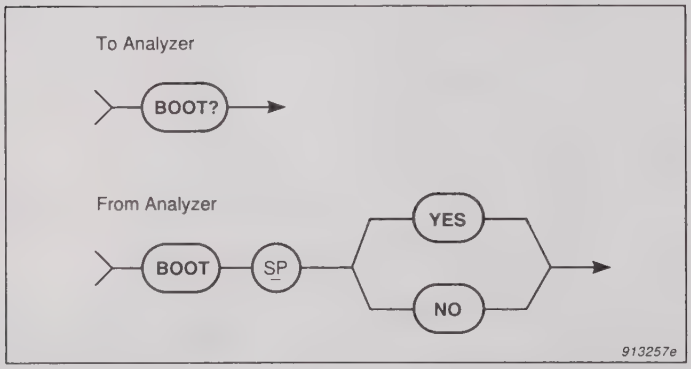

Fig. 5.3(a) Syntax for the BOOT? query message and analyzer response

If the analyzer responds with **YES**, then you can transfer the new program immediately, using the **LOAD** command message (see Fig.5.3(c)). If the response to **BOOT?** is **NO** then you must send the **BOOT** command message (Fig. 5.3(b)), before sending **LOAD**.

Note:

The **BOOT(?)** and **LOAD** messages must be sent in full, there are no mnemonic codes.

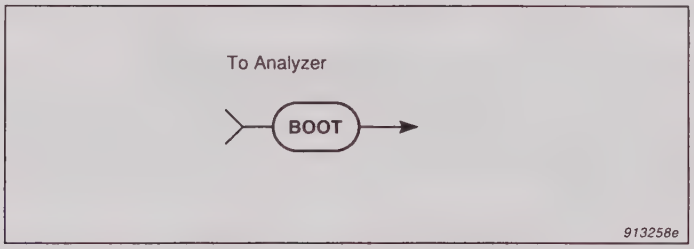

Fig. 5.3(b) Syntax for the BOOT command message

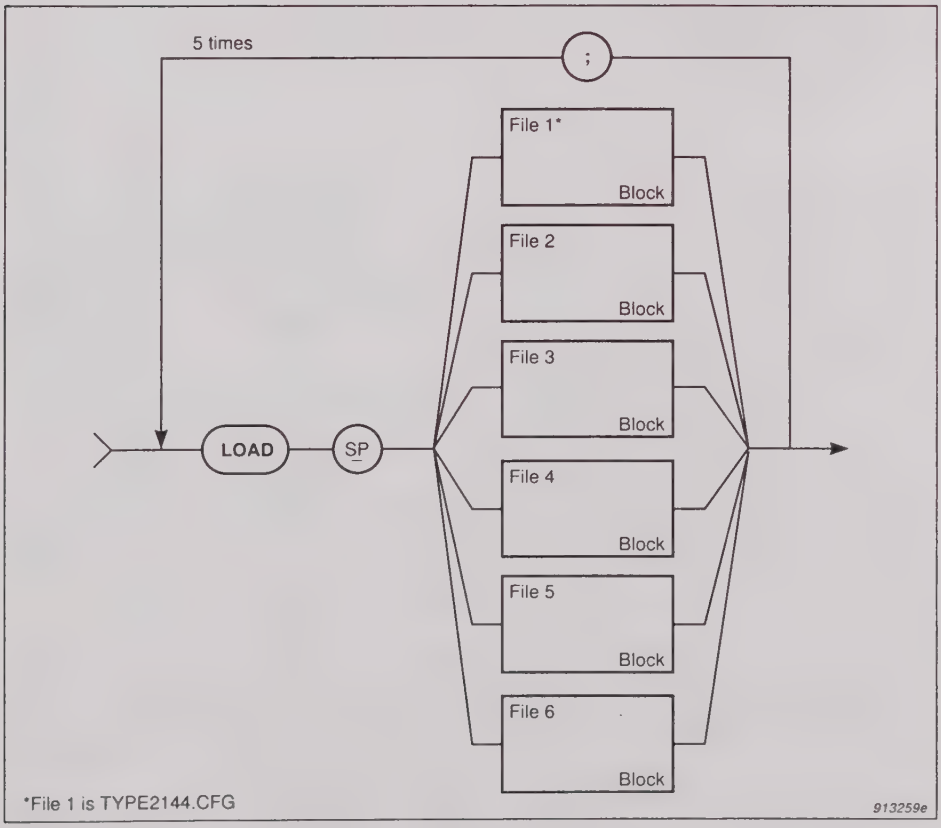

Fig. 5.3(c) Syntax for the LOAD command message

Notes:

- File 1 in Fig 5.3(c) is the "Bootload Configuration File", named TYPE2144.CFG. This file **must always** be sent to the analyzer first. The remaining five files, described in the configuration file LOAD lines, are then sent. All six files **must** be sent to the analyzer in the order specified.
- When you load a new program you delete the existing contents of the data memory.

After the last file has been transmitted, the loaded measurement program starts automatically. If the analyzer cannot load the program for some reason, an error message is displayed on the screen. The bootload error messages are listed in Tables 5.3(a), 5.3(b) and 5.3(c).

Error no.	Error Message	Description
①	IEEE-488 LOAD ABORTED BY DEVICE CLEAR COMMAND	Load cancelled because SDC or DCL was received
9001	UNEXPECTED END OF IEEE-488 TRANSMISSION	More data needed to complete Load
9003	UNKNOWN IEEE HEADER	A header other than Boot(?) or Load was received
9004	IEEE SYNTAX ERROR	Check the syntax of the last IEEE message sent
9101	DISK ERROR	The disk containes a physical error
9103	FILE PROTECTED	Internal Error – please report to B & K
9104	DISK PROTECTED	Internal Error – please report to B & K
9105	NO DISK SPACE	Internal Error — please report to B & K
9106	NO DISK	Check that disk is in disk drive
9107	BAD DISK	Not a DOS disk
9108	FLOPPY JOB ERROR	Internal Error — please report to B & K
9109	NO DIRECTORY SPACE	Internal Error – please report to B & K
9110	DUPLICATE FILE NAME	Internal Error – please report to B & K
9111	NO VOLUME LABEL	Internal Error – please report to B & K
9112	BREAK	Internal Error – please report to B & K
9113	DISK REMOVED DURING USE	Check that disk is in disk drive
9114	BAD DIRECTORY	Directory is incorrect or non-existent
9115	INVALID FILE NAME	The configuration file is corrupted
9116	UNKNOWN ERROR FROM FLOPPY	Internal Error – please report to B & K
9200	EOF	Internal Error – please report to B & K
9201	ERROR IN CONFIG FILE, WRONG SYNTAX IN A LOAD LINE	The configuration file is corrupted
9202	COMMENT LINE OR DESCR LINE	Internal Error – please report to B & K
9203	CRC_TABLE TOO SMALL	Internal Error – please report to B & K

① Not a device error

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Table 5.3(a) Bootload error messages

Error no.	Error Message	Description
9204	ERROR IN CONFIG FILE, DEST_ID IS TOO LONG	The configuration file is corrupted
9205	ERROR IN CONFIG FILE, FILE NAME IS TOO LONG	The configuration file is corrupted
9206	ERROR IN CONFIG FILE, UNKNOWN COMMAND	The configuration file is corrupted
9207	ERROR IN CONFIG FILE, UNKNOWN DEST_ID	The configuration file is corrupted
9208	ERROR IN PROGRAM FILE, NOT IN B & K COFF FORMAT	A program file is corrupted
9209	TOO MANY SECTION HEADERS	Internal Error – please report to B & K
9210	EXIT WITH UNEXPECTED STATE	Internal Error – please report to B & K
9211	ERROR IN CONFIG FILE, ILLEGAL CHARACTER	The configuration file is corrupted
9212	PASSED LINE LGT IN CONFIG FILE	Internal Error – please report to B & K
9213	ERROR ON INTERFACE PARAMETERS - INITIALIZED	Interface parameters have been lost – replaced with default values
9214	NO DISK DURING SEARCH	Internal Error – please report to B & K
9215	CONF. FILE NOT FOUND	Internal Error – please report to B & K
9300	DSP LOADED	Internal Error – please report to B & K
9301	NO CODE LOADED FOR DSP	Internal Error – please report to B & K
9302	NO SPACE IN GLOBAL_DATA_BUFFER	Internal Error – please report to B & K
9303	CRC ERROR IN DSP CODE	Internal Error – please report to B & K
9304	MAIN PROGRAM NOT VALID	The last program loaded has been corrupted. Load a new program

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Table 5.3(b) Bootload error messages

Error no.	Error Message	Description
9305	UNABLE TO LOAD DSP1	Hardware Error – please report to B&K
9306	UNABLE TO LOAD DSP2	Hardware Error – please report to B&K
9312	DP WRITE TIMEOUT	Internal Error – please report to B&K
9313	ERROR IN COMM. WITH DP - INITIALIZED	Internal Error – please report to B&K
9314	DEST_ID OUT OF RANGE	Internal Error – please report to B&K
9315	HP CRC_TABLE TOO SMALL	Internal Error – please report to B&K
9316	HT CRC_TABLE TOO SMALL	Internal Error – please report to B&K
9317	TOO MANY CRC_ELEM TO DP	Internal Error – please report to B&K
9318	ODD COUNT IN HP CRC BLOCK	Internal Error – please report to B&K
9319	ODD COUNT IN HT CRC BLOCK	Internal Error – please report to B&K
9320	"NO-LOAD" DSP CHECK-SECTION NOT ALLOWED	Internal Error – please report to B&K
9321	INVALID DEVICE NAME	Internal Error – please report to B&K
9322	DEST_ID OUT OF RANGE	Internal Error – please report to B&K
9322	DEST_ID OUT OF RANGE	Internal Error – please report to B&K
9323	SOURCE OVERRUN	Internal Error – please report to B&K
9324	DEST. OVERRUN	Internal Error – please report to B&K
9325	ID ERROR	Internal Error – please report to B&K
9400	REACHED EDF BEFORE THE SPECIFIED BYTE COUNT	Internal Error – please report to B&K
9401	FILE NOT FOUND	A file named in the configuration file cannot be found

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Table 5.3(c) Bootload error messages

Chapter 6

Setup Messages

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6.1. Measurement_Type (M_T)

The command message is used to set the **M_T** data field and display the **M**easurement_**T**ype menu. The query message returns a readout of the current **M_T** data field.

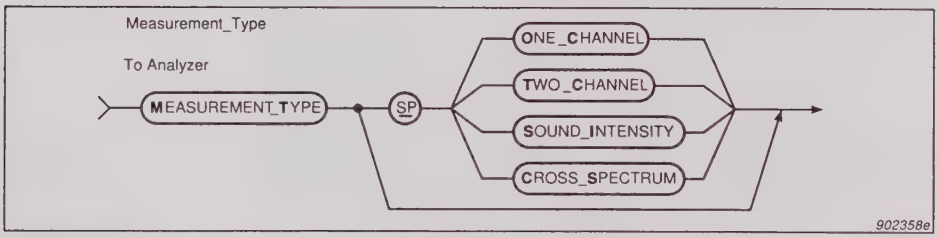

Fig. 6.1(a) Syntax for the M_T command message

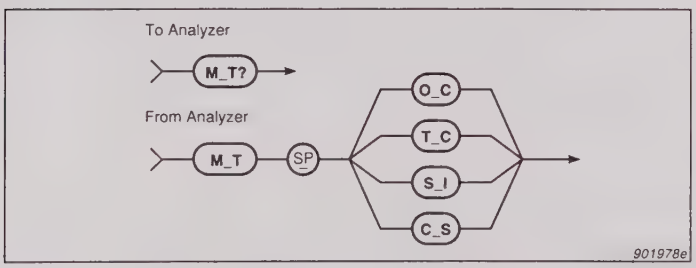

Fig. 6.1(b) Syntax for the M_T? query message and analyzer response

6.2. INput (IN)

The command message is used to set one or more of the **IN** data fields and display the **IN**put menu. The query message returns a readout of all current **IN** data fields. The data fields and their settings are listed in Table 6.1.

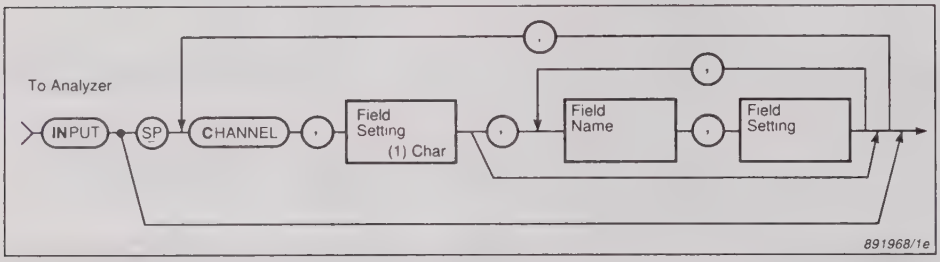

Fig. 6.2(a) Syntax for the IN command message

Note:

You must select Channel **before** selecting any of the other data fields.

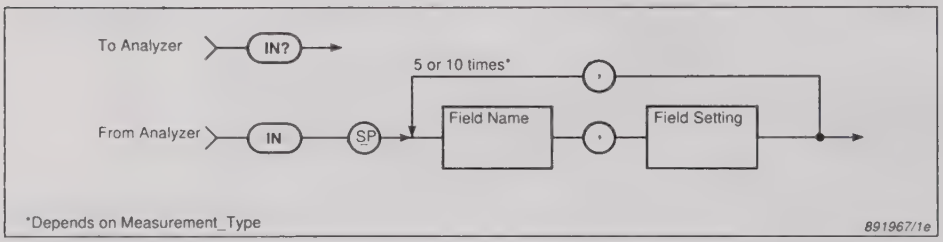

Fig. 6.2(b) Syntax for the IN? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Channel	**A** **B**	Char.	Only A_Ch in 1-channel mode
Type_Of_Input	**D**irect **P**reamp **C**harge	Char.	 Not with A_Weighting ①
Filter	**H**igh_Pass_**0.3** **H**igh_Pass_**0.7** **H**igh_Pass_**2**0 **H**igh_Pass_**1**00 **A**_Weighting	Char.	Only with Charge Not with Charge
Low_Pass	**ON** **OF**f	Char.	Only with Charge
Max_Input	<numeric>	NR1/3② with suffix③	
Input_Protection	**ON** **OF**f	Char.	

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① Before setting the Type_Of_Input to Charge it is recommended first to set the Filter setting
② Depends on whether Y-axis unit is dB or Absolute
③ With suffix unit dB or Absolute, Max_Input is independed of Y-axis unit

Table 6.1 INput data fields and codes

6.3 Filter_Bandwidth (F_B)

The command message is used to set one or more **F_B** data fields and to display the **F**ilter_**B**andwidth menu. The query message returns a readout of all current **F_B** data fields. Table. 6.2(a) shows legal combinations of **B**andwidth and **U**pper_**F**requency. The data fields and their settings are listed in Table 6.2.(b).

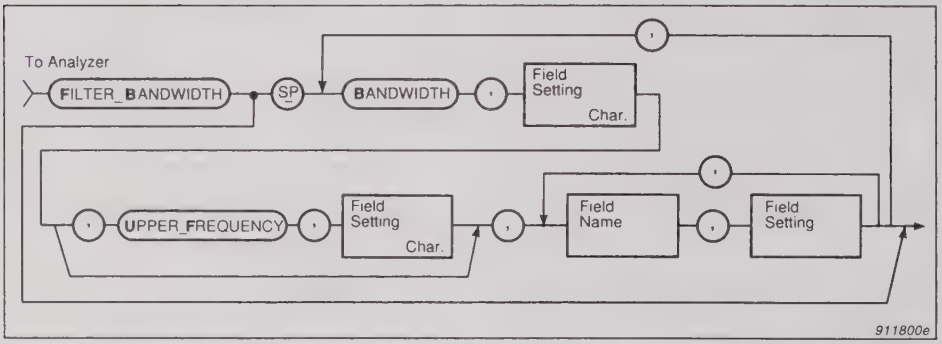

Fig. 6.3(a) Syntax for the F_B command message

Note:

The **B**andwidth and **U**pper_**F**requency fields must be set up in the order shown in Fig. 6.3(a).

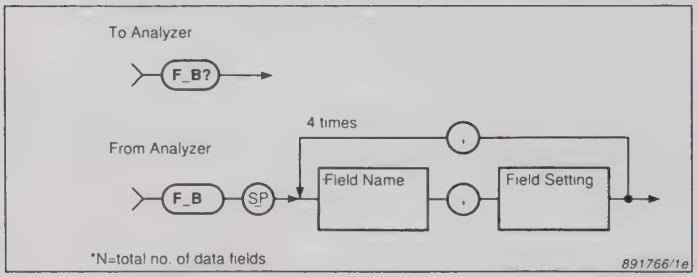

Fig. 6.3(b) Syntax for F_B? query message and analyzer response

Upper	Bandwidth (Octaves)			
Freq.	**1/1**	**1/3**	**1/12**	**1/24**
11.2 kHz	Real Time	Real Time	4 Pass	8 Pass
5.6 kHz			2 Pass	4 Pass
2.8 kHz			Real Time	2 Pass
1.4 kHz				Real Time

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Table 6.2(a) Allowable combinations of bandwidth and upper frequency for 2-ch

Field Name	Field Setting	Data Type	Comments
Bandwidth	**O**ctave_**1** **O**ctave_**3** **O**ctave_**1**_**2** **O**ctave_**24**	Char.	See fig. 3.3 for allowable combinations of B and U_F
Upper_**F**requency	1.4;2.8;5.6;11.2; 22.4 kHz	NR3 (with suffix)	1.4 kHz only in 2-channel, Cross and Intensity 22.4 kHz only in 1-channel. ①
Multi_**P**ass_**A**nalysis	**A**uto **M**anual	Char.	
Lowest_**R**eliable_ **F**requency	10 mHz–100 Hz	NR3 (with suffix)	
Time_**I**nterval_ **B**etween_**P**asses ②	—	NR3	Not settable, value depends on L_R_F setting

T02729GB1

1. Before setting the Upper_Frequency field it is recommended first to set the Bandwidth field
2. Exists as input message, but has no effect

Table 6.2(b) Filter_Bandwidth data fields and codes

6.4. CAlibration (CA)

The command message is used to set one or more specified **CA** data fields and display the **CA**libration menu. The query message returns a readout of current **CA** data fields for all inputs (with the exception of **A**uto_**C**alibration and **C**alibration_**A**veraging_**T**ime). The data fields and their settings are listed in Table 6.3.

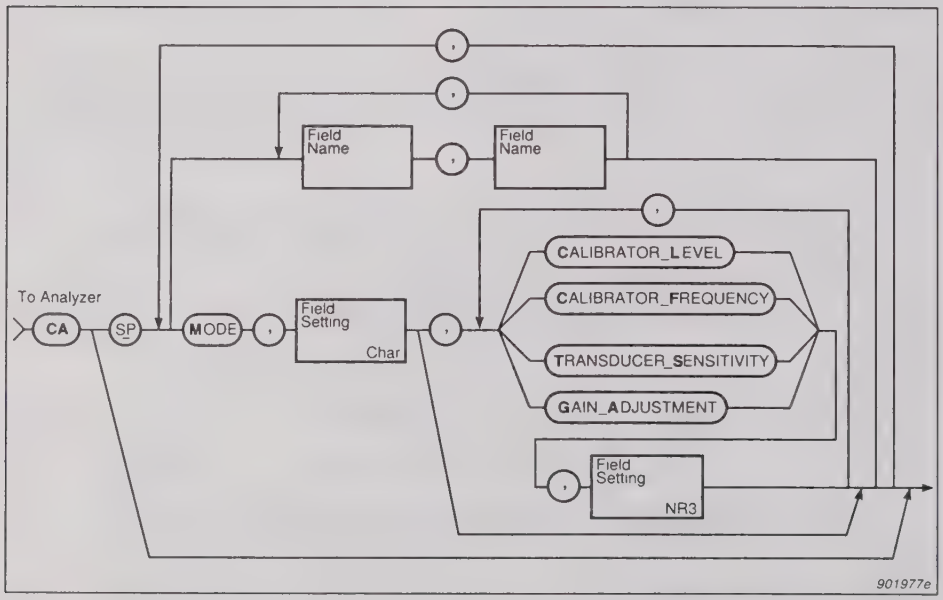

Fig. 6.4(a) Syntax for the CA command message

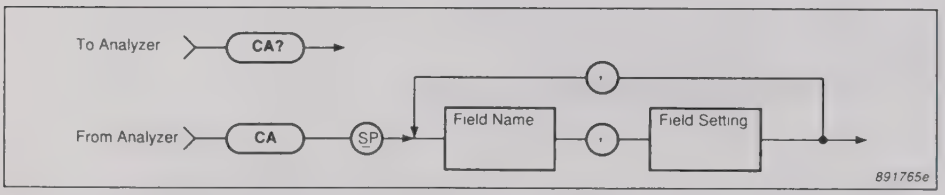

Fig. 6.4(b) Syntax for the CA? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Reference	**A** **B** **Re_Im** **P** **V** **I_J**	Char.	1-ch. } 2-ch. } Cross } Intensity
User_**R**eference		NR3	
Nominal_**S**pacing	1 to 500	NR1	
Ambient_**T**emperature	–25 to 100	NR2	Deg. Celcius
Ambient_**P**ressure	650 to 1100	NR1	Default unit hPa.
Air_**D**ensity	0.0001 to 12	NR3 (with suffix)	Default unit kg/m
User_**D**ensity	0.0001 to 12	NR3 (with suffix)	Default unit kg/m
Mode	A B A_B I V	Char.	In 1-Ch. mode only A is available. A_B is only available in Intensity mode. I and V are only for verification of intensity calibration
Calibrator_**L**evel		NR3	see note in the Input message for max_Input
Calibrator_**F**requency		NR3	
Transducer_**S**ensitivity		NR3	
Gain_**A**djustment		NR3	see note in the Input message for max_Input
Calibration_**A**vg_**T**ime	2;4;8;16	NR1	Time in Seconds
Auto_**C**alibration	**S**tart	Char.	Input only
Verification_**A**vg_**T**ime	2;4;8;16	NR1	Time in Seconds
Auto_**V**erification	**S**tart	Char.	Input only

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Table 6.3 CAlibration data fields and codes

6.5. COrrection (CO)

The command message is used to set one or more specified **CO** data fields and display the **CO**rrection menu. The **CO?** query message returns a readout of all current **CO** data fields. The data fields and their settings are listed in Table 6.4.

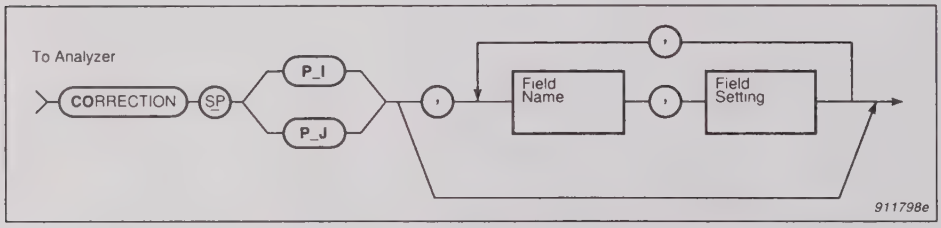

Fig. 6.5(a) Syntax for the CO command message

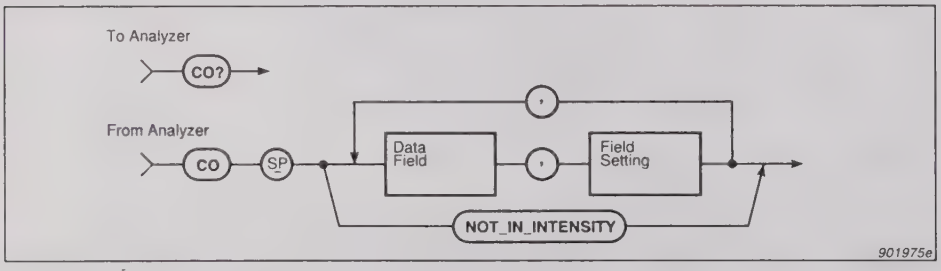

Fig. 6.5(b) Syntax for the CO? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Range_**H**igh_**F**req		NR3	
Range_**L**ow_**F**req		NR3	
Averaging_**T**ime	24 H to 1 ms	NR3	
Correction	**ON** **OF**f	Char	
Save_**C**orrection ①	[none]		

① Input message only

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Table 6.4 COrrection data fields and codes

6.6. AVeraging (AV)

The command message is used to set one or more specified **AV** data fields and display the **AV**eraging menu. The query message **AV?** returns a readout of all current **AV** data fields. The data fields and their settings are listed in Table 6.5.

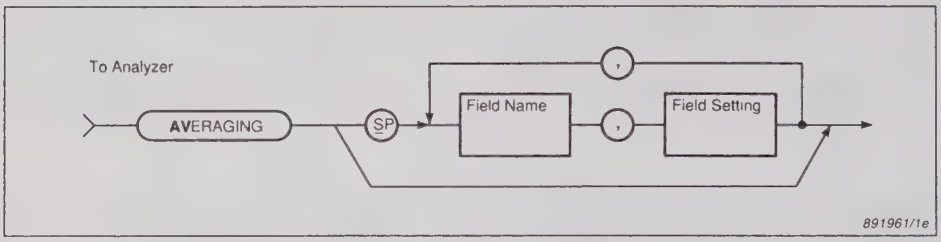

Fig. 6.6(a) Syntax for the AV command message

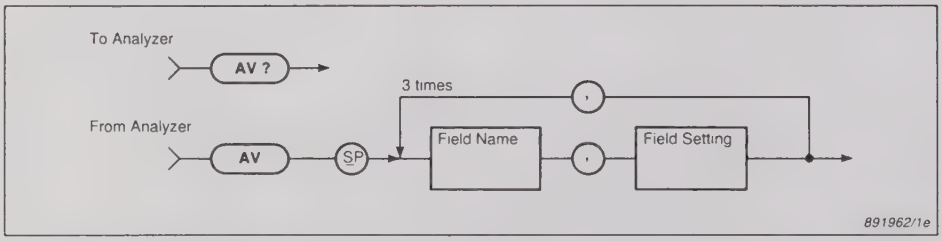

Fig. 6.6(b) Syntax for the AV? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Averaging_**M**ode	**L**inear **E**xponential	Char.	
Lin_**A**vg_**T**ime	1 **MS** to 24 **H**rs	NR3 (with suffix)	Default is seconds If units other than seconds are required, the suffixes H, M and MS can be used
Exp_**A**vg_**T**ime	1/512 to 512 s	NR3	Time in seconds. Internal values must be whole powers of 2[1]
Auto_**R**ange_**T**ime	0,1 to 59,9	NR2	In seconds

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[1] Fractions are expressed using decimal on exponential notation
e.g $^1/_{512} \simeq 0.002$ or 1.95E–03

Table 6.5 AVeraging data fields and codes

6.7. Display_Mode (D_M)

The command message is used to set one or more specified **D_M** data fields and to display the **D**isplay_**M**ode menu. The query message **D_M?** returns a readout of all current **D_M** data fields. The data fields and their settings are listed in Tables 6.6(a) and 6.6(b).

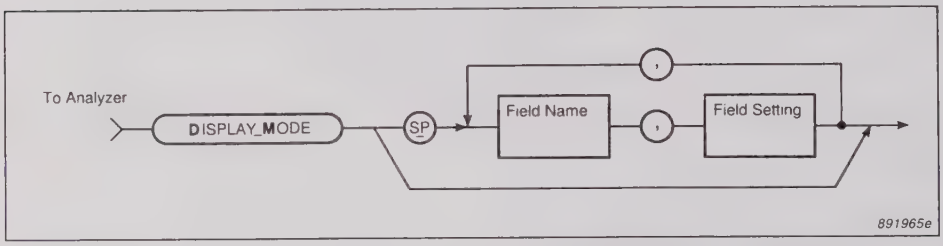

Fig. 6.7(a) Syntax for the D_M command message

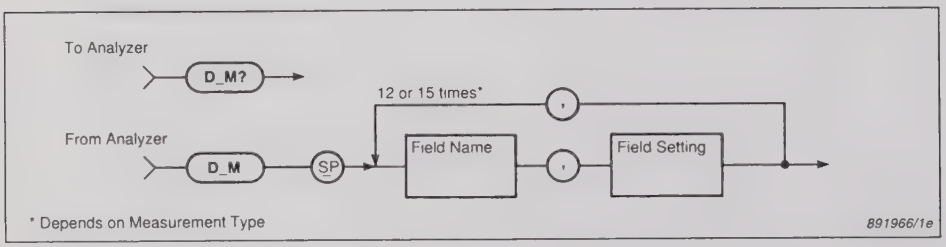

Fig. 6.7(b) Syntax for the D_M? query message and analyzer response

Field Name	Setting	Data Type	Comments
Mode_**O**ptions	**SI**ngle **DU**al **DI**fference	Char.	
Y_Axis_**U**nit	**DB** **A**bsolute	Char.	
Highest_**C**entre_**F**requency		NR3 (with suffix)	
Lowest_**C**entre_**F**requency		NR3 (with suffix)	
SPectrum	**U**nipolar **B**ipolar	Char	Only for Intensity and Cross
Full_**S**cale_**U**pper		NR3	①
Full_**S**cale_**L**ower		NR3	①
Displayed_**A**mplitude_ **R**ange_**U**pper	10;20;40;80	NR1	Always in dB
Displayed_**A**mplitude_ **R**ange_**L**ower		NR1	Always in dB

[1] See Note in the INput message for Max_Input

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Table 6.6(a) Display_Mode data fields and codes

Field Name	Setting	Data Type	Comments
Spectrum_Unit_Upper	PWr Rms ENg PSd ESd	Char.	
Spectrum_Unit_Lower		Char.	
Differentiationor_ Integration_Upper	Differentiated_Twice DIfferentiated None Integrated Integrated_Twice	Char.	
Differentiationor_ Integration_Lower		Char.	
Diff_Amplitude_Range	1;5;10;20;40;80	NR1	Always in dB
Displayed_Phase_ Range_Upper	0.2;1;5;45;90;180	NR1	Only for Intensity and Cross
Displayed_Phase_ Range_Lower			

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Table 6.6(b) Display_Mode data fields and codes

6.8. Hold (H)

The command message is used to set one or more specified **H** data fields and display the **H**old menu. The **H?** query message returns a readout of all current **H** data fields. The data fields and their settings are listed in Table 6.7.

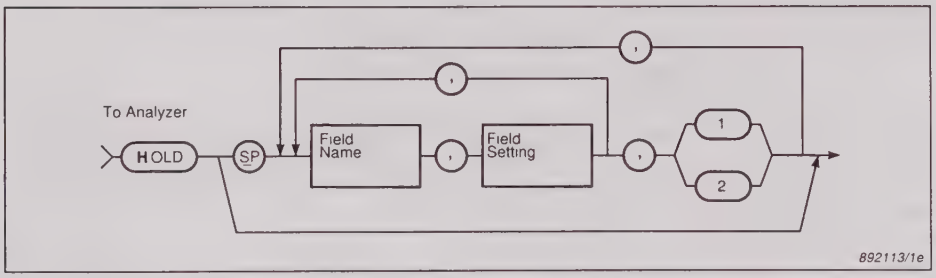

Fig. 6.8(a) Syntax for the H command message

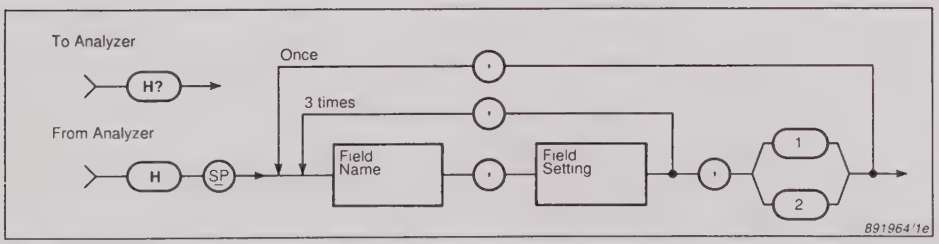

Fig. 6.8(b) Syntax for the H? query message and analyzer response

Note:

"2" is not available in single channel mode.

Field Name	Field Setting	Data Type	Comments
Type	**MA**x **MI**n	Char.	
MOde	Inactive **A**ll_**C**hannels **A**_**L**_**C**hannel **W**_**C**hannel **B**and_**P**ass_**F**ilter	Char.	
Band_**P**ass_**F**ilter_ **C**entre_**F**requency		NR3 (with suffix)	Automatically rounded to nearest centre frequency
Spectrum	**A**uto_**A** **A**uto_**B** **C**ross_**R** **C**ross_**I** **M**ean_**P** **V**elocity **R**eac_**J** **I**ntensity	Char.	1-Ch, 2-Ch: Cross Inten-sity

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Table 6.7 Hold data fields and codes

6.9. Spectrum_Weighting (S_W)

The command message is used to set one or more specified **S_W** data fields and display the **S**pectrum_**W**eighting menu. The **S_W?** query message returns a readout of all current **S_W** data fields. The data fields and their settings are listed in Table 6.8.

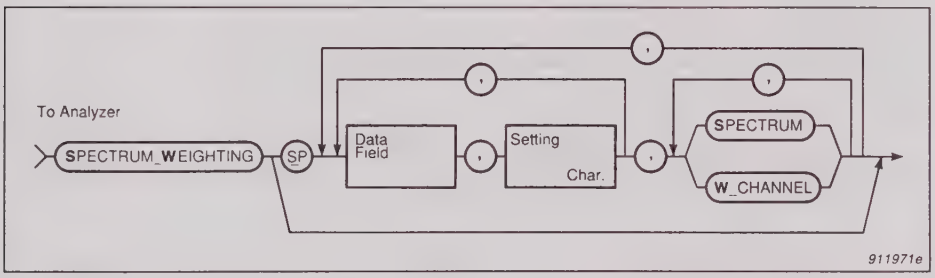

Fig. 6.9(a) Syntax for the S_W command message

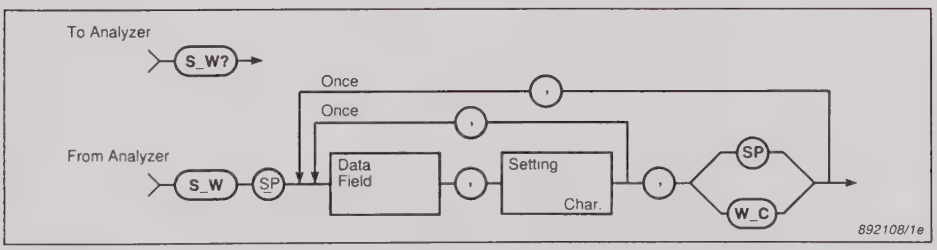

Fig. 6.9(b) Syntax for the S_W? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Weight	Linear_Weighting U1 U2 U3 U4 A_Weighting B_Weighting C_Weighting D_Weighting	Char.	
Inverse	ON OFf	Char.	

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Table 6.8 Spectrum_Weighting? data fields and codes

6.10. Defined_Weight_Function (D_W_F)

The command message is used to enter a given weight function, by a method corresponding to manual entry via Page 2 of the Spectrum_Weighting menu. **D_W_F** without any data field(s) displays Page 2 of the Spectrum Weighting menu. The **D_W_F?** query message returns a readout of all user-defined weight functions.

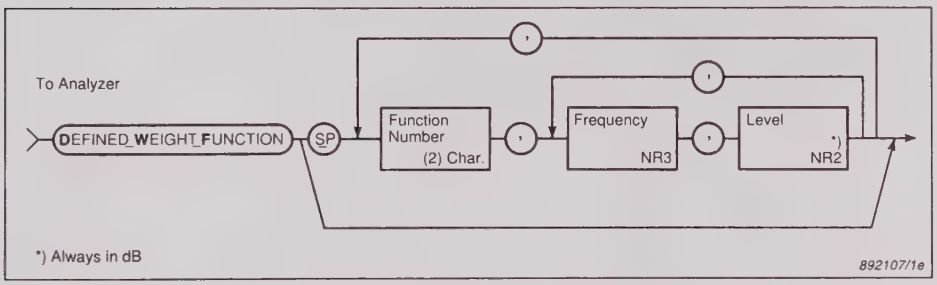

Fig. 6.10(a) Syntax for the D_W_F command message

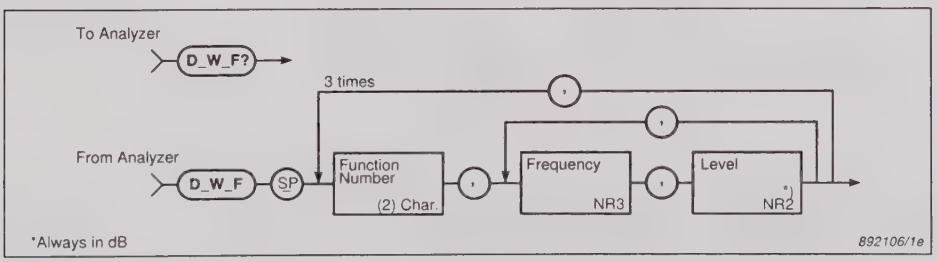

Fig. 6.10(b) Syntax for the D_W_F? query message and analyzer response

Note: Function number can be **U1**, **U2**, **U3** or **U4**.

6.11. Real_Time_Clock (R_T_C)

The command message is used to display page 2 of the Real_Time_Clock menu and set the 'Clock' data fields. The **R_T_C?** query message reads out all current Clock data fields. The data fields and their settings are listed in Table 6.9.

Notes:

- Sending the **R_T_C** header without any data fields displays Page 2 of the Real_Time_Clock menu.
- Data fields concerned with **Wake_Up** functions are described in section 6.12.

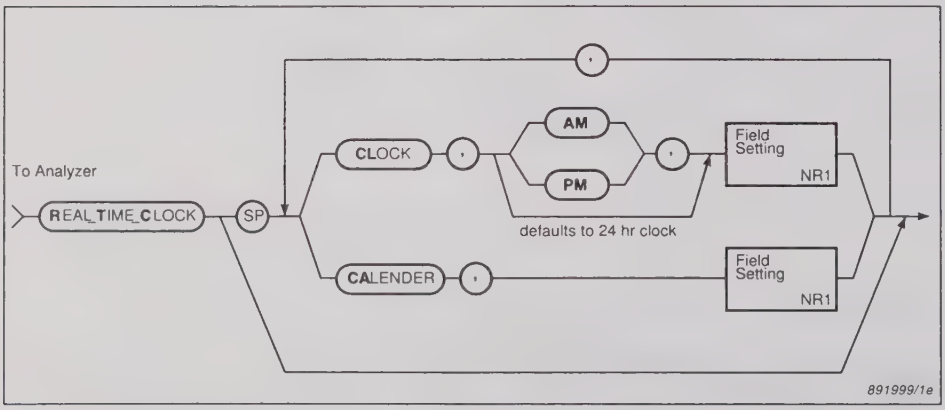

Fig. 6.11(a) Syntax for the R_T_C command message

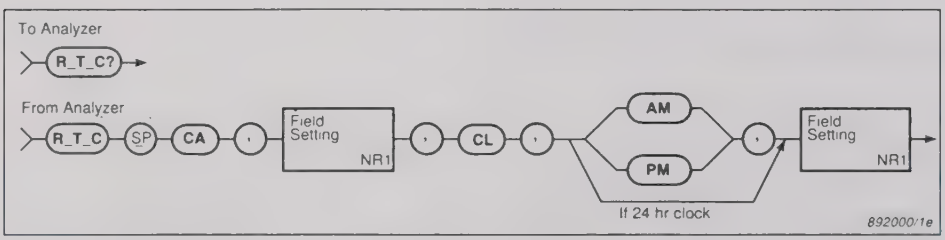

Fig. 6.11(b) Syntax for the R_T_C? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
CAlender	<integer>	NR 1	YYYYMMDD
CLock	**A**m, <integer> **P**m, <integer> <integer>	Char. NR 1	HHMMSS Integer only defaults to 24 hr clock.

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Table 6.9 Real_Time_Clock data fields and codes

6.12. Wake_Up (W_U)

The command message is used to set the **W_U** data fields in the **Real_Time_Clock** menu and display Page 1 of the menu. The query message returns a readout of all **Wake_Up** data fields. The data fields and their settings are listed in Table 6.10.

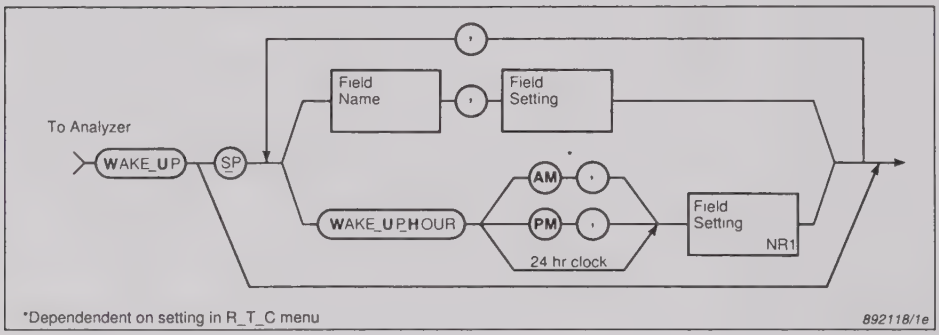

Fig. 6.12(a) Syntax for the W_U command message

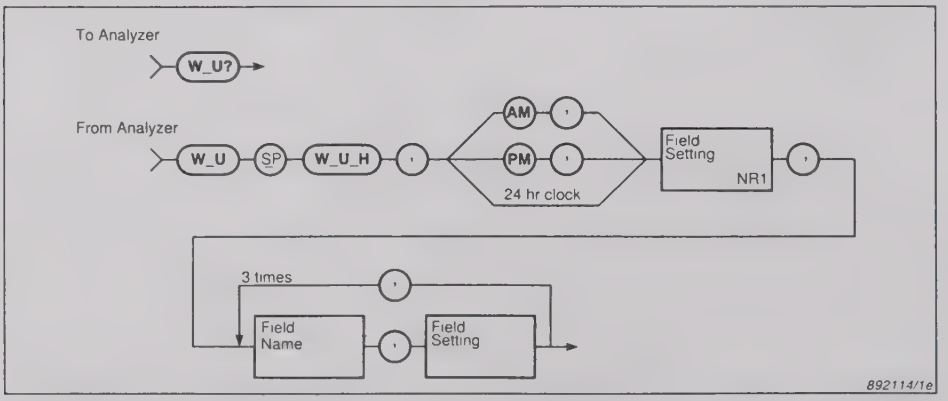

Fig. 6.12(b) Syntax for the W_U? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Wake_**U**p_**H**our	**A**m, <integer> **P**m, <integer> <integer>	Char. NR1	HHMM Depends on R_T_C setting. Nothing defaults to 24 hr clock
Wake_**U**p_**I**nterval	1 **M**inute to 24 **H**ours	NR2 (with suffix)	Minutes expressed as decimal fractions of an hour, e.g. 1.5 H = 1 hr 30 min. 90 M = 1 hr 30 min. Default is hours
Numberof_**W**ake_**U**ps	1–9999	NR1	Sets no. of "wake ups"
Wake_**U**p	**AC**tive **I**nactive	Char.	See note
Elapsed_**N**umberof_ **W**ake_**U**ps	0–9999	NR1	Exists as input message, but has no effect

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Table 6.10 Wake_Up data fields and codes

Note:

If **W**ake_**U**p is set to **AC**tive, 10 seconds elapses, then the analyzer switches itself off and consequently deactivates the interface. When the analyzer "wakes up" again it will automatically reactivate the interface.

6.13. Measurement_Text_Predefine (M_T_P)

The command message is used to edit the numbered texts in the **M**easurement_**T**ext menu, and to display Page 2 of that menu. The query message returns a readout of all numbered texts in the **M**easurement_**T**ext menu. The **M_T_P** data fields and their settings are listed in Table 6.11.

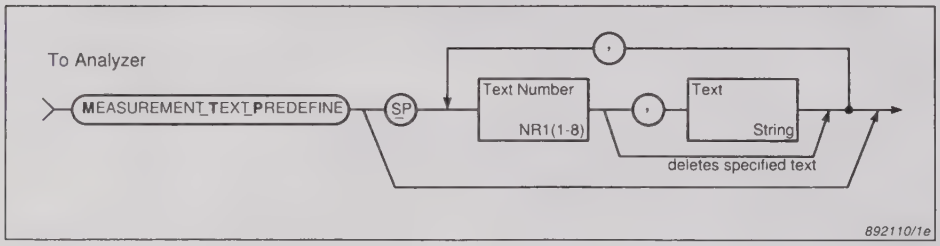

Fig. 6.13(a) Syntax for the M_T_P command message

Example:

To enter the first text field, the controller sends:

```
M_T_P 1,"ABCDEF"
```

Data Field	Data Type
Text No.	NR1
Text	String ①

[1] Max. 40 char. T02290GB0

Table 6.11 Measurement_Text_Predefine data fields

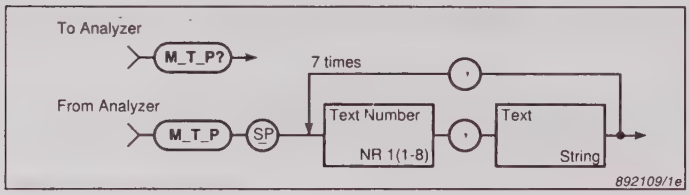

Fig. 6.13(b) Syntax for the M_T_P? query message and analyzer response

Example:

To obtain a readout of the text fields, the controller sends:

```
M_T_P?
```

The analyzer responds with (for example):

```
M_T_P 1,"ABCDEF    ",2,"GHIJKL      ",3,"...
```

6.14. Measurement_Text_Select (M_T_S)

The **M**easurement_**T**ext_**S**elect command message is used to select one of the predefined texts from the **M**easurement_**T**ext menu, and to display Page 1 of that menu.

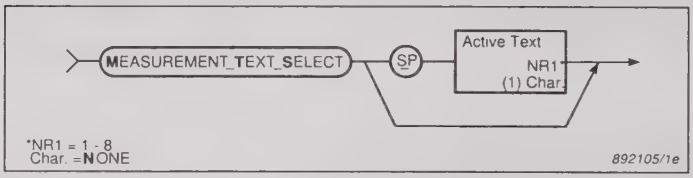

Fig. 6.14 Syntax for the M_T_S command message

6.15. Trigger (T)

The command message is used to set one or more specified **T** data fields and to display the **T**rigger menu. The query message returns a readout of all current **T** data fields. The data fields and their settings are listed in Tables 6.12(a) and 6.12(b).

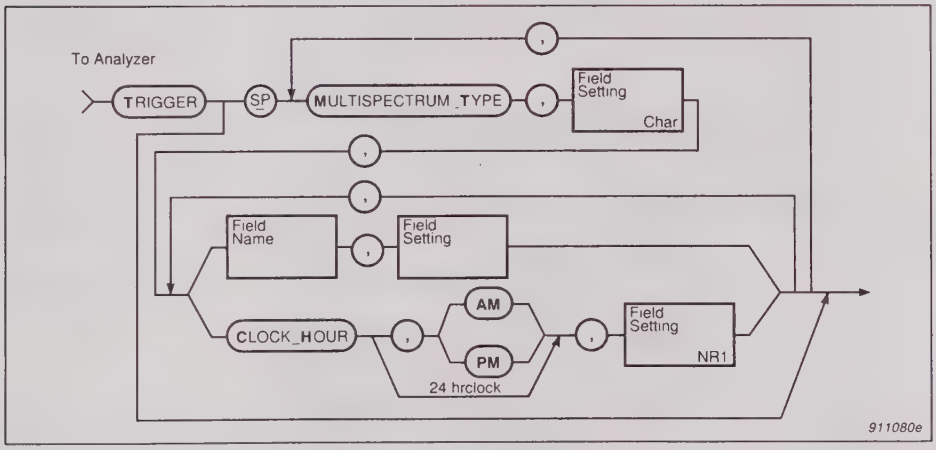

Fig. 6.15(a) Syntax for the T command message

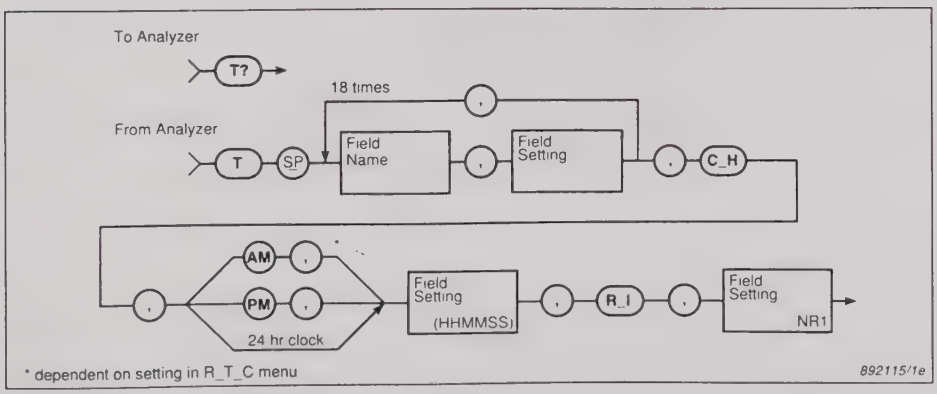

Fig. 6.15(b) Syntax for the T? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Trigger_Mode	Inactive ACtive	Char.	
Trigger_Select	External Internal Time Manual Free_Run	Char.	
Multispectrum_Type	NOrmal Gated Matrix	Char.	
Time_Delay		NR3	Seconds. A negative value in 'Normal' = pretrig
Numberof_Spectraper_Trigger		NR1	
Time_Interval_Between_Spectra		NR3	Seconds Only applies to normal triggering
Gating_Width		NR3	Only applies to gated triggering
Numberof_Trigger		NR1	Only applies to normal triggering
Numberof_Rows		NR1	
Numberof_Columns		NR1	
Numberof_Directions	1 to 3	NR1	
Space between_Rows		NR3	Default is mm
Space between_Columns		NR3	Default is mm

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Table 6.12(a) Trigger data fields and codes

Field Name	Field Setting	Data Type	Comments
Measurement_ **S**equence	**DCR** **DRC** **CDR** **CRD** **RDC** **RCD**	Char.	
Trigger_**L**evel		NR3	①
Trigger_**C**hannel	**A_L_C**hannel **W_C**hannel **B**and_**P**ass_**F**ilter	Char.	
Band_**P**ass_**F**ilter_ **C**hannel_**F**requency	<numeric> { **MI** / **Hz** / **K**Hz }	NR3 (with suffix)	Defaults to Hertz **MI** upper case, or lower case **m** for millihertz
SLope	**NE**gative **PO**sitive	Char.	
SPectrum	**A**uto_**A** **A**uto_**B** **C**ross_**R** **C**ross_**I** **M**ean_**P** **V**elocity **R**eac_**J** **I**ntensity	Char.	1-Ch, 2-Ch } Cross } Inten-sity
Clock_**H**our	**AM,** <integer> **PM,** <integer> <integer>	Char. NR1	HHMMSS Integer only defaults to 24 hr clock
Repetition_**I**nterval	<numeric> { **M**inutes / **S**econds }	NR2 (with suffix)	default is seconds

[1] See Note in the INput message for Max_Input

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Table 6.12(b) Trigger data fields and codes

6.16. Preselected_SEtup (P_SE)

The command message is used to send a Preselected Setup to the analyzer in block data (binary) format and to change between the different Preselected Setups. You can activate a **M**easurement setup, **D**isplay setup or the **C**alibration setup from either default values or a set of stored values. The query message returns a readout of a specified setup in binary or ASCII format. The data fields and their settings are listed in Table 6.13.

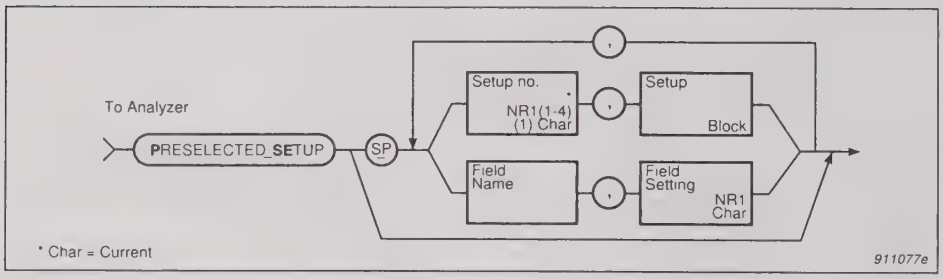

Fig. 6.16(a) Syntax for the P_SE command message

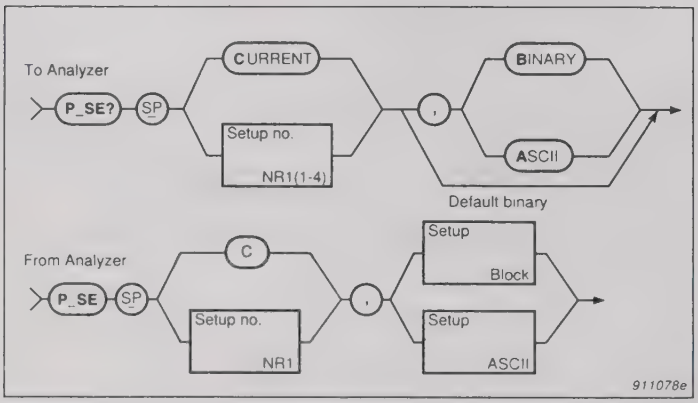

Fig. 6.16(b) Syntax for the P_SE? query message and analyzer response

Header/Field Name	Field Setting	Data Type	Comments
Select	1 2 3 4 Acoustic Vibration	NR1 Char.	
Activate	Measurement Display Calibration	Char.	

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Table 6.13 Preselected_SEtup data fields and codes

Examples:

The controller sends:

```
P_SE? C
```

The analyzer responds with:

```
P_SE C, #3727<block data>
```

The controller sends:

```
P_SE? 1,A
```

The analyzer responds with:

```
P_SE 1<CR><LF>
M_T C_S<CR><LF>
etc
```

Details of the data format for storage of block data in analyzer files are given in Chapter 10.

Note:

When the RS–232–C interface is used to transfer binary block data, 8 data bits are needed

6.17. Memory_Data (M_D)

6.17.1 M_D Command Message

The command message is used to set one or more specified **M_D** data fields and to display the **M**emory menu. The syntax for the command message is given in Fig. 6.17(a).

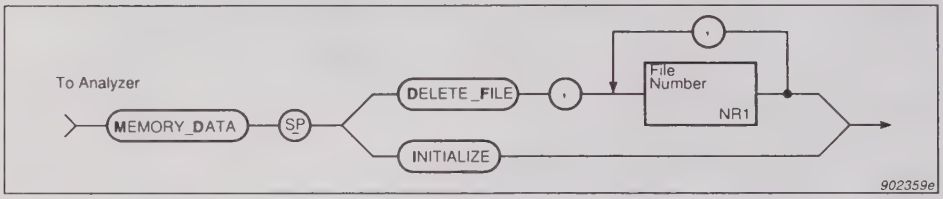

Fig. 6.17(a) Syntax for the M_D command message

6.17.2 M_D? Information Query Message

This query message is used to read out general information about the status of the spectrum memory over the interface. This information is also displayed on page 2 of the Memory menu.

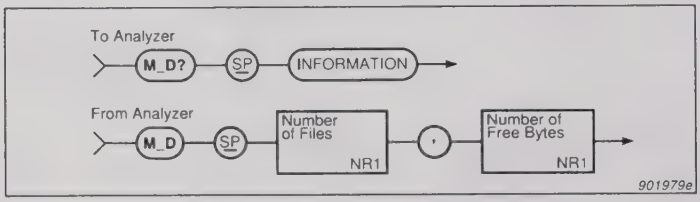

Fig. 6.17(b) Syntax for the M_D? Information query message and analyzer response

6.17.3 M_D? File List Query Message

In response to this query message, the analyzer lists all the files stored in the data memory, sorted according to which data field is specified.

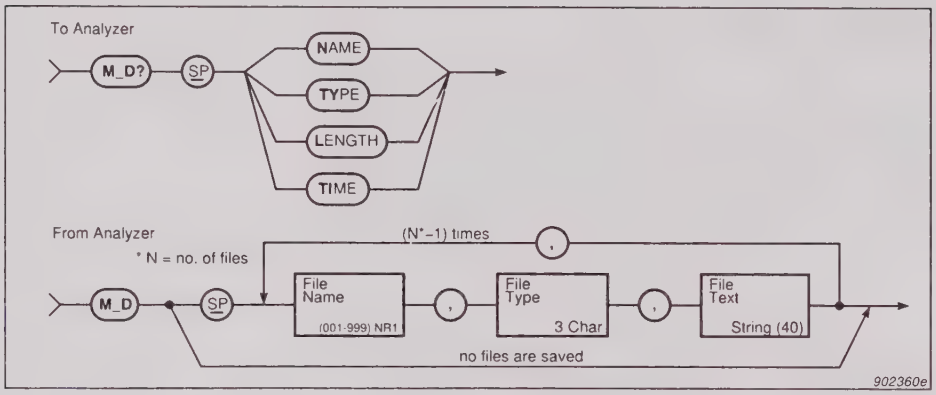

Fig. 6.17(c) Syntax for the M_D? file list query message and analyzer response

6.17.4 M_D? Overload Query Message

This query message is used to determine whether a particular file contains an overload. This could be used after a multispectrum measurement, to determine whether an overload has occurred in one of the spectra.

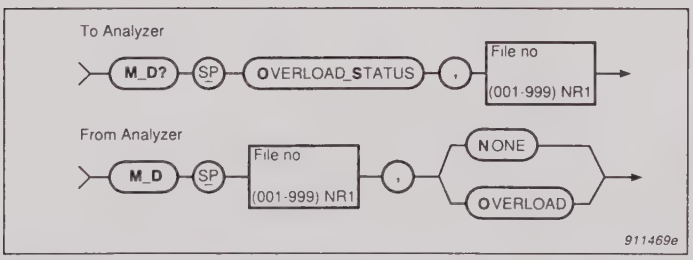

Fig. 6.17(d) Syntax for the M_D? Overload query message and analyzer response

6.18. Boom_Mux (B_M)

The command message is used to set one or more specified **B_M** data fields and display the **B**oom_**M**ux application menus. The query message returns a readout of all the **B_M** Common_**S**etup data fields, and either the **D**ecay or **SP**l fields, depending on which has been selected. The data fields and their settings are listed in table 6.14.

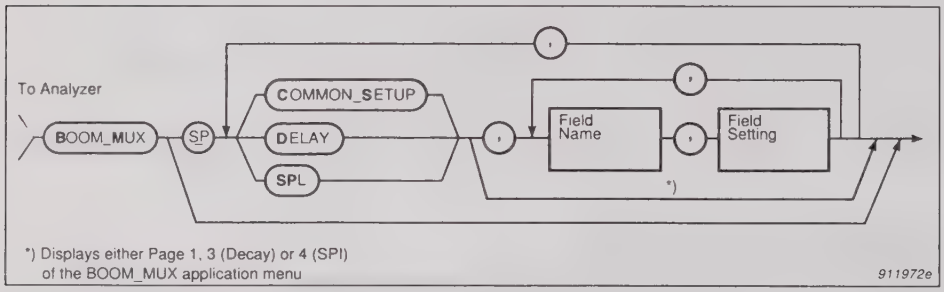

Fig. 6.18(a) Syntax for the B_M command message

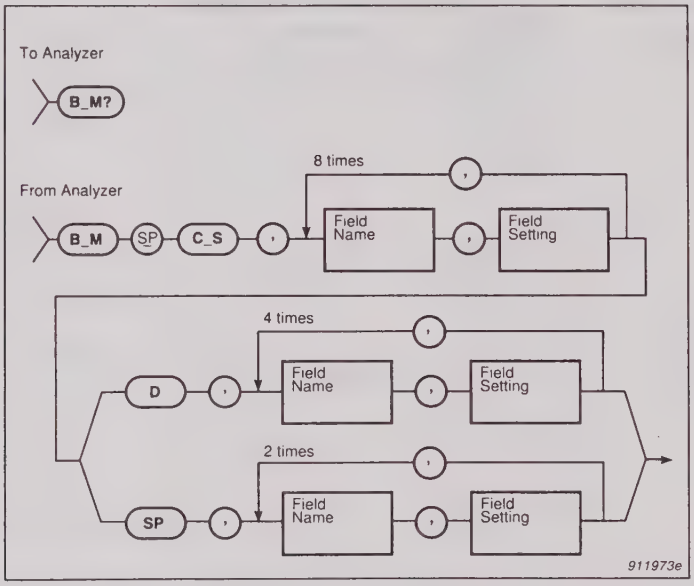

Fig. 6.18(b) Syntax for the B_M? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Boom_**M**ux_**S**ound_ **S**ource_**A**ppl	**A**ctive **I**nactive	Char	**C**ommon_**S**etup
Sound_**S**ource	**OF**f 1 2 **B**oth	Char NR1	
Auto_**R**ange	**ON** **OF**f	Char.	
Auto_**R**ange_**T**ime	<numeric>	NR3	
Delaybefore_ **M**easurement_**S**tart	<numeric>	NR1	
Equipment_**T**ype	**B**oom **M**ux **N**one	Char	
Positioning_**M**ode	**SI**ngle **ST**ep **R**otating	Char	
Single_**P**osition_**N**umber	<numeric>	NR1	
Number_**S**tep_**P**ositions	<numeric>	NR1	

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Table 6.14(a) Boom_Mux data fields and codes with Common_Setup

Field Name	Field Setting	Data Type	Comments
Sound_Source_On_Time	<numeric>	NR1	Decay
Averaging_Mode	Linear Exponential	Char	
Time_Interval_ Between_Spectra	<numeric>	NR3	
Spectraper_Excitation	<numeric>	NR1	
Spectrabefore_Sound_ Source_Off	<numeric>	NR1	
Excitationsper_Position	<numeric>	NR1	
Sound_Source_On_ Timebefore_Meas	<numeric>	NR1	SPl
Measurement_ Timeper_Step_Rota	<numeric>	NR3	
Delaybefore_Measurement	<numeric>	NR3	

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Table 6.14(b) Boom_Mux data fields and codes with Decay and SPl

Chapter 7

Device Control Messages

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7.1 Service_Request_Enable (S_R_E)

Note:

This message is only available with IEEE–488

The **S**ervice_**R**equest_**E**nable command message is used to define the SRE mask. This determines which events generate a service request. The query message (**S_R_E?**) reads out the current decimal value of the SRQ mask. Table 7.1 describes the 8 bits of the 2143 status byte. Table 7.2 lists the SRQ functions which relate to these, along with a brief explanation of their use.

Note: When the interface is made ACTIVE, all bits are disabled.

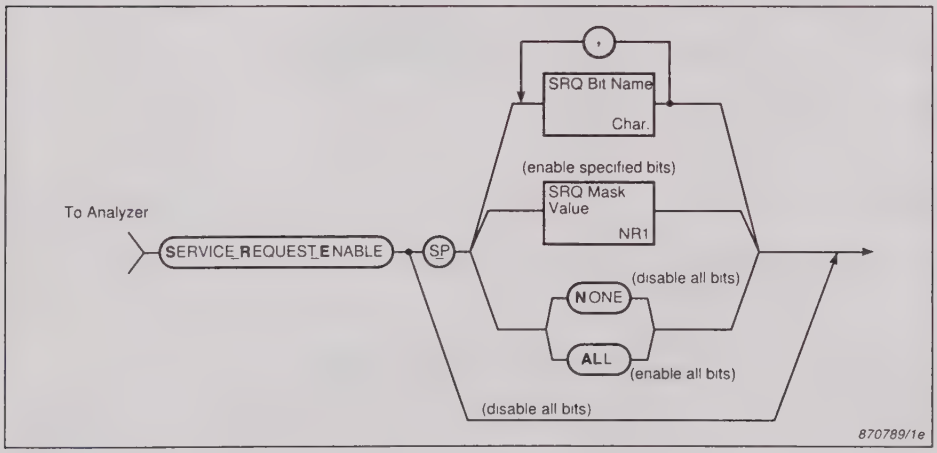

Fig. 7.1(a) Syntax for the S_R_E command message

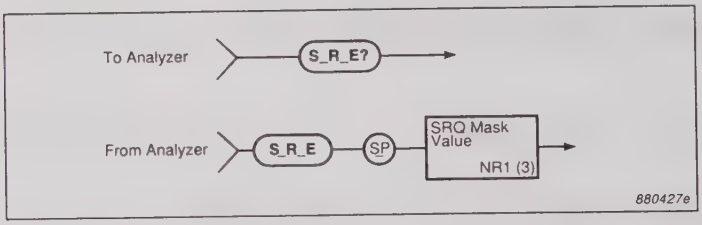

Fig. 7.1(b) Syntax for the Service_Request_Enable query message and analyzer response

Bit no.	8	7	6	5	4	3	2	1
Binary Weighting	128	64	32	16	8	4	2	1
Designation	key pressed	service request	abnor-mal	busy	input overload	trigger accepted	global warning	data available

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Table 7.1 The 2144 Status Byte

Example of Use:

```
S_R_E DATA_AVAILABLE,KEY_PRESSED

S_R_E 129
```

These two messages are equivalent, both set the mask bit pattern "10000001". The second message uses the decimal value of the bit pattern (1 + 128 = 129).

In this example the analyzer generates a service request:

- When it has finished processing the current data, and
- Whenever a key is pressed.

Note: A Service Request for Data_Available occurs after each pass in Pass_Measurement.

SRQ Functions			
Bit No.	**Bit Name**	**Data Type**	**Status Indication**
1	**D**ata_**A**vailable	Char.	Set when RMS processor finished[1] and latest data received by display
2	**G**lobal_**W**arning	Char.	Set when power supply (battery) voltage is low or analogue module is protected
3	**T**rigger_**A**ccepted	Char.	Set when triggering conditions are satisfied
4	**I**nput_**O**verload	Char.	Set when an analogue or digital input overload occurs
5	[Busy][2]		Set if the analyzer has not finished processing the previous input message[3]
6	**AB**normal	Char.	Set when an error condition occurs
7	[SRQ][2]		Set by the analyzer if one of the other bits is set[3] (except bit 5)
8	**K**ey_**P**ressed	Char.	Set if one of the analyzer's pushkeys has been pressed[4]
(1 to 8)	**ALl** **N**one	Char.	Enable all bits in the status byte Disable all bits in the status byte
–	[Bit Pattern][2]	NR1	Sets a selected combination of the above – NR1 is the decimal value of the bit pattern

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[1] In the case of a multispectrum Data_Available is set when the last spectrum is finished
[2] Not codes
[3] Cannot be enabled by the user.
[4] In REMote without local LoCKout (LLO), this bit is set only when Local or SRQ keys are pressed. In REMote with LLO, the bit is set only when the SRQ key is pressed

Table 7.2 SRQ Functions

7.2 Define_Terminator (D_T)

The **D**efine_**T**erminator message (command only) is used to define the ASCII character with which the analyzer terminates output messages, and which it recognises as the terminating character of input messages. See section 4.1.5 for further information.

By default, i.e. unless user-defined, the terminator is the line feed character <LF>. All the ASCII control characters, with the exception of 13, or <CR> can be used as terminators. See Table 7.3 below.

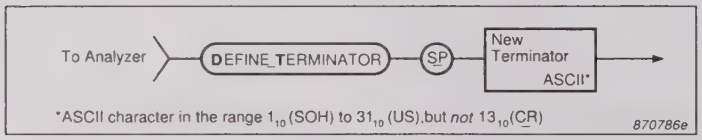

Fig. 7.2 Syntax for the D_T command message

Bit Numbers b_7 b_6 b_5 / b_4 b_3 b_2 b_1	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
0 0 0 0	NUL	● DLE	SP	0	@	P	‘	p
0 0 0 1	● SOH	● DC1	!	1	A	Q	a	q
0 0 1 0	● STX	● DC2	“	2	B	R	b	r
0 0 1 1	● ETX	● DC3*	#	3	C	S	c	s
0 1 0 0	● EOT	● DC4	$	4	D	T	d	t
0 1 0 1	● ENQ	● NAK	%	5	E	U	e	u
0 1 1 0	● ACK	● SYN	&	6	F	V	f	v
0 1 1 1	● BEL	● ETB	’	7	G	W	g	w
1 0 0 0	● BS	● CAN	(	8	H	X	h	x
1 0 0 1	● HT	● EM	)	9	I	Y	i	y
1 0 1 0	● LF	● SUB	*	:	J	Z	j	z
1 0 1 1	● VT	● ESC	+	;	K	[	k	{
1 1 0 0	● FF	● FS	,	<	L	\	l	¦
1 1 0 1	CR	● GS	–	=	M	]	m	}
1 1 1 0	● SO	● RS	.	>	N	‾	n	~
1 1 1 1	● SI	● US	/	?	O	_	o	DEL

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* see note below

Table 7.3. ASCII characters. The allowed terminators are indicated by ●

Note:

With RS–232–C operation it is not advisable to use <DC3>, ASCII 19, as the message terminator, as this provides the RS–232–C X - Off function.

7.3 Error_Stop (E_S)

The **E**rror_**S**top message (command only) is used to determine what action the 2144 takes when an error is detected. The data field following the **E_S** header can be **Y**es or **N**o, determining whether or not the **E**rror_**S**top function is active.

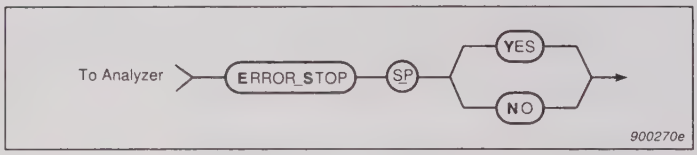

Fig. 7.3 Syntax for the E_S command message

Error_**S**top works differently for the two interfaces. When **E**rror_**S**top **Y**es is selected:

- **IEEE 488** - when an error is detected, the 2144 stops the hanshake with the bus, indicating to the controller that there is an error. After receiving a Device Clear (DCL) or Selected Device Clear (SDC), the 2144 resets the parser and resumes data reception. The parser is also reset and data reception resumed if the controller executes a serial poll or if the 2144 is requesting service.

- **RS–232–C** - when an error is detected, the 2144 discards any character received except BREAK. After receiving a BREAK, parsing is restarted.

When **E**rror_**S**top **N**o is selected:

- **IEEE 488** - hanshaking continues but all subsequent data is ignored until an End message (Char ∧ EOI). Parsing is then restarted.

- **RS–232–C** - when an error is detected, the 2144 discards all subsequent data until it receives a <BREAK>. After receiving a <BREAK>, parsing is resumed.

Note:

Error_Stop is automatically set to **N**o in the following cases:

- The interface is manually switched from INACTIVE to ACTIVE
- The analyzer has been reset, either manually, or via the interface
- The analyzer has been switched OFF and ON again.

7.4 Reset_Status_Byte (R_S_B)

Note:

This message is only available with IEEE–488.

The **R**eset_**S**tatus_**B**yte message (command only) is used to return the status byte to its default setting. In this way a service request can be cancelled without performing a serial poll. All the status byte bits are set to zero.

Fig. 7.4 Syntax for the R_S_B command message

7.5 IDentify? (ID?)

IDentify? (query only) returns a readout of the instrument type. If version B of the message is sent, then the input module identification (analog type) and the software version number are also returned.

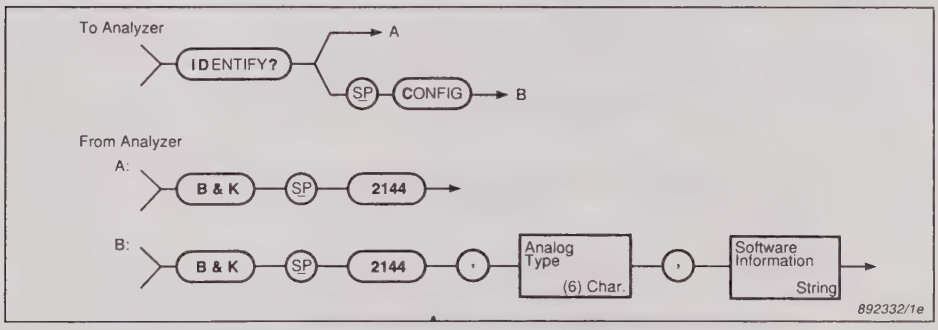

Fig. 7.5 Syntax for the ID? query message and analyzer response

Example:

The controller sends:

```
ID? C
```

The analyzer returns:

```
B&K 2144,ZN0497,"VP7278,101,1,100,101,100,111"
```

7.6 Update (U)

Update (command only) is used to choose the update mode for the 2144 display. The alternatives are listed in Table 7.4.

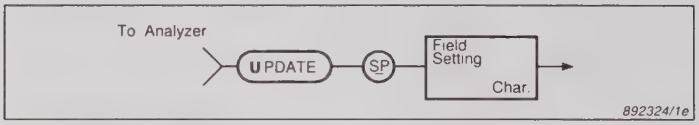

Fig. 7.6 Syntax for the U command message

Field Setting	Data Type	Comments
Update_Meas	Char.	Only displays changes in the Measurement menus i.e. Measurement Mode, Calibration and Internal Trigger
Update_All	Char.	Displays all changes and the 'affected' menu. This is the default setting

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Table 7.4. Update data fields

7.7 AWait (AW)

AWait (command only) locks the IEEE interface until a particular event occurs. NRFD (Not Ready For Data) is held back until the specified event occurs (NRFD hold). The events are specified in the syntax diagram below.

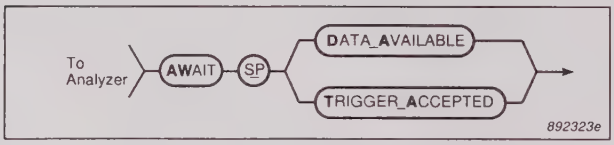

Fig. 7.7 Syntax for the AW command message

Notes:

- **AW**ait cannot be used with the RS–232–C interface
- The IEEE bus is released after each pass in Pass_Measurement
- NRFD hold is not active for any Universal or Addressed bus commands sent by the controller e.g. DCL, SDC, GET, etc.

7.8 Averaging_Mode (A_M)

Averaging_**M**ode (command only) is used to choose between linear and exponential averaging.

Note: A_M can also be set up using the **AV**eraging message.

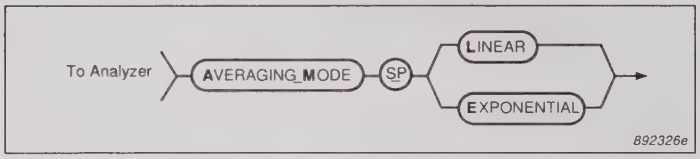

Fig. 7.8 Syntax for the A_M command message

7.9 Averaging_Control (A_C)

Averaging_Control (command only) is used to start, continue and stop an averaging operation.

Note:

If **A_C STA**rt is received when the analyzer is not in measurement mode, it switches to measurement mode automatically, and then starts the measurement.

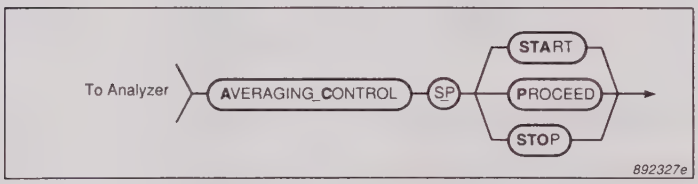

Fig. 7.9 Syntax for the A_C command message

7.10 Measurement_Mode (M_M)

Measurement_**M**ode is used to set one or more specified **M_M** data fields and to display the **M**easurement_**M**ode menu. The command data fields and their settings are listed in Tables 7.5(a) and 7.5(b). The query message returns a readout of the data fields listed in Tables 7.5(c).

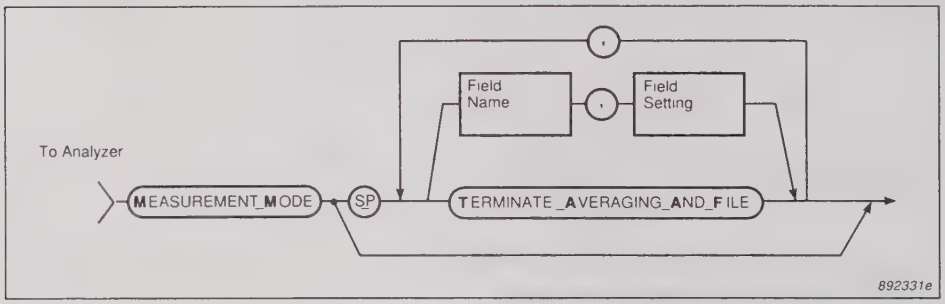

Fig. 7.10(a) Syntax for the M_M command message

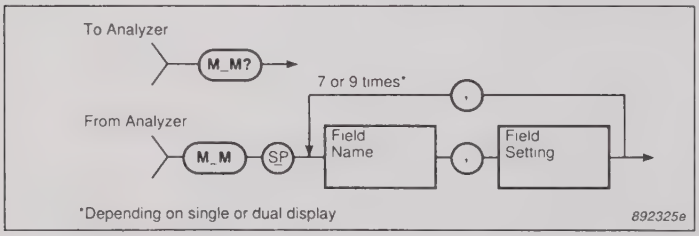

Fig. 7.10(b) Syntax for the M_M query message and analyzer response

Field Name	Field Setting	Data Type	Comments
Centre_Frequency Centre_Frequency_ Upper Centre_Frequency _Lower	<numeric> { m[1]Hz / Hz / KHz }	NR3 (with suffix)	Default is hertz Range of centre frequencies depends on bandwidth
Align_Cursor	ON OFf	Char.	
Select_Spectrum_Type Select_Spectrum_ Type_Upper Select_Spectrum_ Type_Lower	Auto_A Auto_B Cross_Re Cross_Im Mean_Pressure Velocity Reactive_J Intensity Phase Magnitude Coherence H1 H2 H3	Char.	1-ch. } 2-ch. } cross } Intensity } cross
Averaging_Time	<numeric> { Seconds / millisecs[1] }	NR3 (with suffix)	Default is seconds. 18 discrete values from 1/256 s to 512 s in binary sequence in exponential.

[1] Lower case m or MI/MS for milli-

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Table 7.5(a) Measurement_Mode data fields and settings (command)

Field Name	Field Setting	Data Type	Comments
Monitor_**S**pectrum_**N**o		NR1	Only in Gated Pass measurement
Save	1–999	NR1	Not used in Normal
Recall **R**ecall to_**U**pper **R**ecall to_**L**ower	1.000–999.999	NR1 NR2	NR2 for a multispectrum
Open_**F**ile	1–999	NR1	Only in Normal, real-time
Terminate_**A**veraging_ **A**nd_**F**ile	[none][1]	–	Only in Normal, real-time
Pass_**N**o		NR1	Only in manual pass measurement
Spectrum_**HO**ld	**ON** **OF**f	Char.	
Display **D**isplay_**U**pper **D**isplay_**L**ower	**HO**ld **C**ontinue	Char.	
Elapsed_**T**ime[2]		NR2	
Averaging_**S**tatus[2]		Char.	

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[1] Not a code
[2] Exist as input messages but have no effect

Table 7.5(b) Measurement_Mode data fields and settings (command)

Field Name	Field Setting	Data Type	Comments
Save		NR1	This is the figure displayed after 'SAVE IN' on the screen of the analyzer
Elapsed_Time		NR2	
Averaging_Status	**RE**ady **RU**nning **P**aused **F**inished **W**aiting **S**ettling **A**uto_**R**ange	Char.	This field can also be read out using the Actual_Status message. See section 7.3
Pass_No		NR1	
Align_Cursor	**ON** **OF**f	Char	
Select_Spectrum_Type _Upper Select_Spectrum_Type _Lower	**A_A** **A_B** **C_R** **C_I** **M_P** **V** **R_J** **I** **P** **M** **C** **H1** **H2** **H3**	Char	
Spectrum_Hold	**ON** **OF**f	Char	
Display_Upper Display_Lower	**HO**ld Continue	Char	

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Table 7.5(c) Measurement_Mode data fields and settings (query)

7.11 Max_Input (M_I)

The Max_Input command message is used to set the input attenuator, either in single steps or by selecting a specified setting. The query message returns a readout of the current setting.

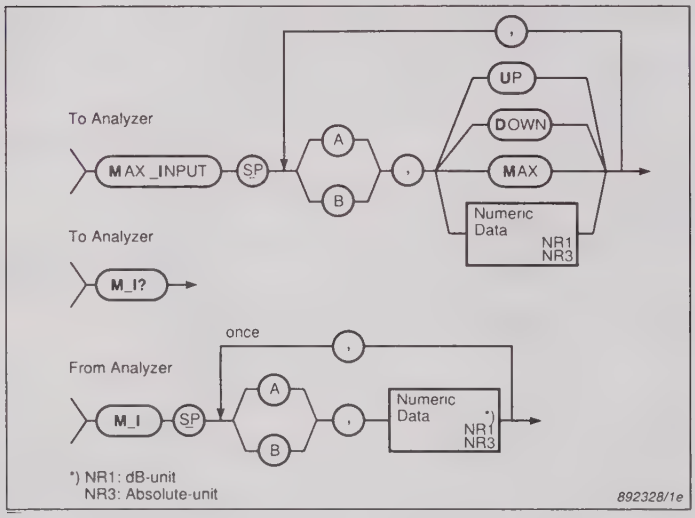


Fig. 7.11 Syntax for the M_I messages

7.12 REMote/LoCKout (REM/LCK)

Note: These messages are only available with the RS–232–C interface.

REMote and **LoCK**out are used to control the Remote/Local function of the analyzer via the RS–232–C interface. Fig. 7.12(c) shows the relationship between the remote and local states.

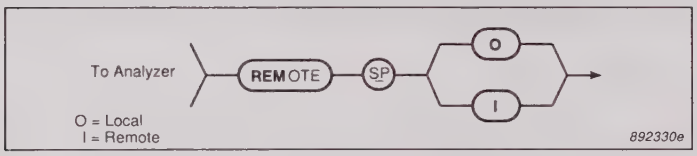


Fig. 7.12(a) Syntax for the REM command message

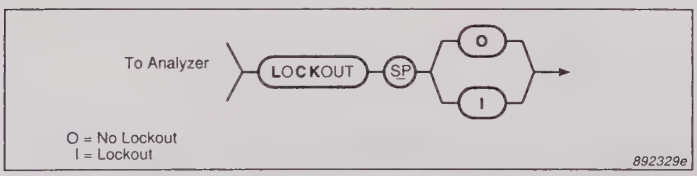


Fig. 7.12(b) Syntax for the LCK command message

Front panel States:

There are four states. Refer to Fig. 7.12(c).

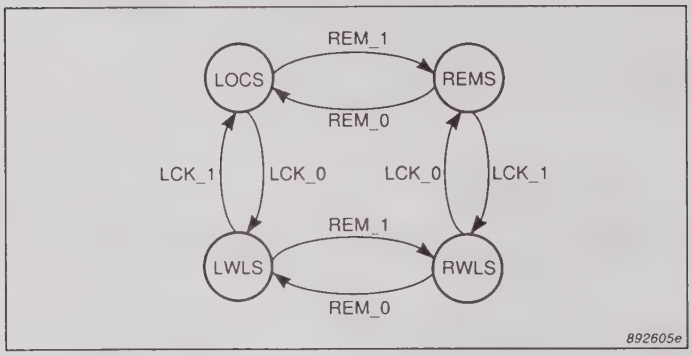


Fig. 7.12(c). Remote / Local state diagram

1. **LOCS** – Local state: front-panel pushkeys all work normally.
2. **REMS** – Remote state: limited front-panel operation (see section 2.5).
3. **RWLS** – Remote with lockout: similar to **REMS**, but the LOCAL pushkey is inoperative.
4. **LWLS** – Local with lockout: front-panel pushkeys all work normally.

Note:

When the interface is made `ACTIVE`, the analyzer is automatically set to the local state (LOCS).

7.13 Group_Trigger (G_T)

Note:

This message has not effect when the RS–232–C interface is selected.

The **G**roup_**T**rigger message allows you to enable the IEEE bus command "Group Execute Trigger" (GET). When GET is **E**nabled, the analyzer responds to a GET command from a controller by generating a 1 μs pulse from the "Trigger Out" socket on the back panel.

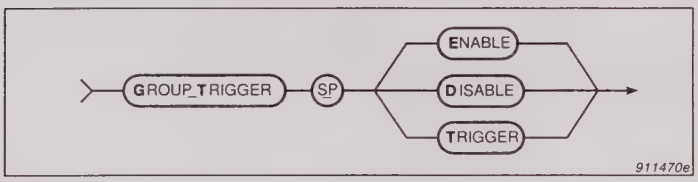


Fig. 7.13 Syntax for the G_T command message

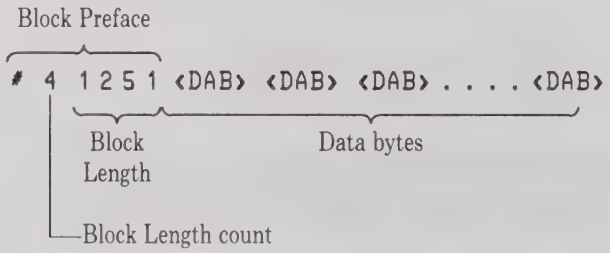
You can also make the analyzer generate its own trigger pulse by sending the message **G**roup_**T**rigger **T**rigger. This allows you to trigger via the RS–232–C interface, though the trigger pulse will be delayed.

7.14 Block_Preface_Length (B_P_L)

The **B**lock_**P**reface_**L**ength command is used to define the length of the block preface. The **B_P_L** header defines the number of characters before the first data byte of a block. Block data is preceeded by block length characters which specify the number of data bytes in the block. The length of the block preface must be greater than, or equal to 2 + the number of characters required to describe the length of the block. The block length count is a single numeric digit which defines the number of digits in the block length. The syntax of the **B_P_L** message is given in Fig. 7.14.

Example:

If the block contains 1251 data bytes then the **B**lock_**P**reface_**L**ength must be set to at least six.



If the **B_P_L** is not large enough, the analyzer will generate an error. If it is not specified by the user or set to **D**efault the analyzer will automatically calculate the correct value. The block length characters are padded with zeros if **B_P_L** is greater than required.

Note:

The number of Block Length characters will always be **B**lock_**P**reface_**L**ength minus two, as two characters are always required for the "#" and the Block Length character.

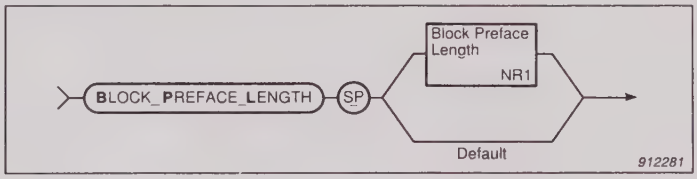


Fig. 7.14 Syntax for the B_P_L command message

B_P_L will always be set to default after:

- A reset, either manual or via the interface.
- The Interface is made ACTIVE.
- The analyzer is turned on.

Chapter 8

Status, Result and Display Messages

8.1 ERror? (ER?) 8–2

8.2 Status_Byte? (S_B?) 8–4

8.3 Actual_Status? (A_S?) 8–5

8.4 Spectrum_Data (S_D) 8–6

8.5 Data_Memory_Read? (D_M_R?) 8–9

8.6 Current_Spectrum_Read? (C_S_R?) 8–11

8.7 Print_SCreen?(P_SC?) 8–13

8.1 Error? (ER?)

ERror? (query only), returns information concerning the most recent analyzer error. This error record comprises the error number (see Chapter 9 for a full list of 2144 interface error messages) and a brief description of the error. It is in the form of a character string of up to 80 characters. The error record is described below, with examples. Fig. 8.1 shows the syntax for the **ER**ror? message.

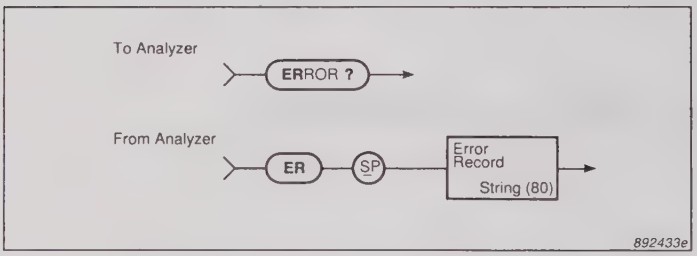


Fig. 8.1 Syntax for the ER? message

After the error record is read out, the record is deleted. If no error has occurred since the last readout of **ER?**, the analyzer returns the message:

```
ER "ERR 000: - NO INTERFACE ERROR"
```

Error Record:

<">
Header: 4 char (1-4)
Error_Number: 3 char (5-7)
Error_Trail: 2 char (8-9)
Error_Text: 20 char (10-29)
Message_Header: 7 char (30-36) [1) 2)]
Error_Buffer: 44 char (37-80) [1) 3)]
<">

Example:

```
ER"ERR 060:  UNKNOWN INDEX      F_B   :
f_b Bandwidth,oct_3,pper_freq,"
```

---

[1] Message_Header and Error_Buffer are left out if the error is the result of a manual operation.

Example: "ERR 060: UNKNOWN INDEX"

[2] Message_Header is left out if the error occurs on receipt of a header, in which case Error_Buffer is located from 30 to 44.

Example: "ERR 060: UNKNOWN INDEX g_b"

[3] Left out if Error_Stop No is chosen.

Example: "ERR 060: UNKNOWN INDEX F_B :"

8.2 Status_Byte? (S_B?)

Status_Byte? (query only) returns a readout of the 2144 status byte. This is similar to the effect of a serial poll performed via the IEEE interface, except that Busy (bit 5) will always be set. The value read out is the decimal value of the bit pattern.

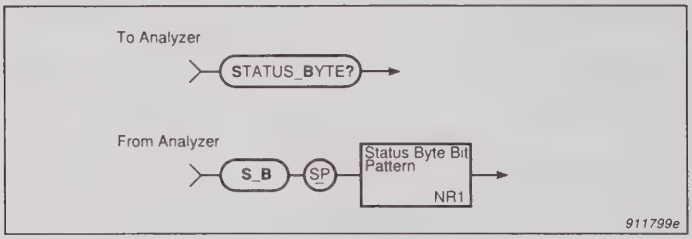


Fig. 8.2 Syntax for the S_B? message

Example:

If you send:
`S_B?`

The analyzer responds (for example) with:

`S_B 144.`

This represents 10010000, i.e. bit 5 (busy) and bit 8 (key pressed) are set.

8.3 Actual_Status? (A_S?)

Actual_**S**tatus? (query only) returns a readout of the status of one of the data fields listed in Table 8.1 (**A**veraging, **I**nput_**O**verload or **G**lobal_**W**arning). The syntax of the **A**ctual_**S**tatus? message is described in Fig. 8.3.

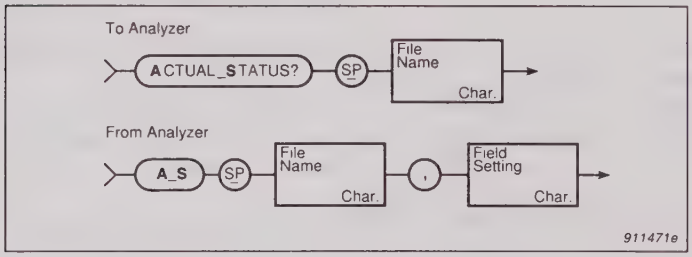


Fig. 8.3 Syntax for the A_S? query message

Field Name	Field setting	Data Type	Comments
Averaging	**RE**ady **RU**nning **P**aused **F**inished **W**aiting **S**etting **A**uto_**R**ange **N**one	Char.	
Input_**O**verload		NR1	8-bits status: Bit 1 (LSB) Common Bit 2 Channel A Bit 3 Channel B Bit 4–8 Not used
Global_**W**arning	**L**ow_**P**ower Input_**P**rotection **N**one	Char.	

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Table 8.1 A_S data fields and settings

8.4 Spectrum_Data (S_D)

The **S**pectrum_**D**ata message is used to load specified spectra into, and to read spectra out of the 2144 spectrum memory. The spectra are input and output in the form of binary block data.

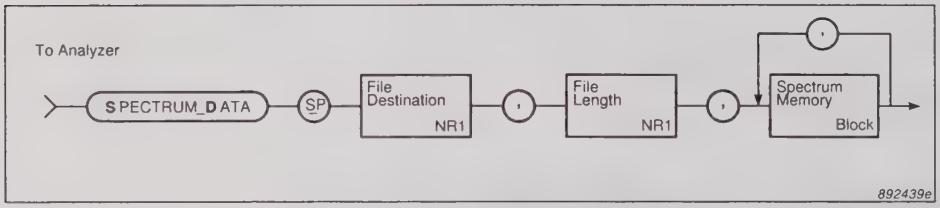

Fig. 8.4(a) Syntax for the S_D command message

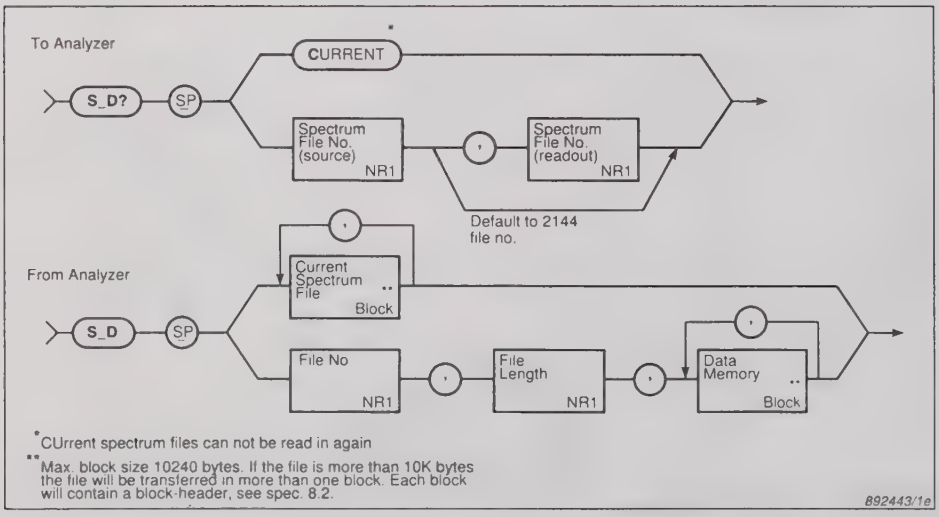

Fig. 8.4(b) Syntax for the S_D? query message and analyzer response

Note:

See sections 4.2.4, 7.14 and Chapter 10, for further details of the format for block data.

Examples:

Current Spectrum
To obtain a readout of the current spectrum, the controller sends:

```
S_D? CU
```

The analyzer responds with:

```
S_D #3160<data>
```

Numbered File
To obtain a readout of File 1 (for 2-ch), the controller sends:

```
S_D? 1
```

The analyzer responds with:

```
S_D 1,681,#3681B&K-2144<data>
```

Change File Number
To read out File 1 as File 100, the controller sends:

```
S_D? 1,100
```

The analyzer responds with:

```
S_D 100,681,#3681B&K-2144<data>
```

For further details of the block data format, see section 4.2.4 and Chapter 10.

Notes:

- Attempting to read in and save a file using a file number which already exists (or an illegal file number) results in the file not being saved. In addition, the analyzer generates an error message, and the **AB**normal bit in the status byte is set. If you do want to use an existing file number then the existing file must first be deleted or renamed.
- If a non-existent file number is specified for output, the **AB**normal bit in the status byte is set and the analyzer generates an error message.

- The Current Spectrum may be read out. However, as it does not have the disk memory format, it **cannot** be loaded back into the 2144. With Current Spectrum, **all** available spectra are read out.
- With RS–232–C operation, 8 data bits must be used.

8.5 Data_Memory_Read? (D_M_R?)

Data_**M**emory_**R**ead? (query only) returns a readout of a specified spectrum or slice from spectrum memory. This readout comprises a description followed by a number of Y values (dB or absolute units).

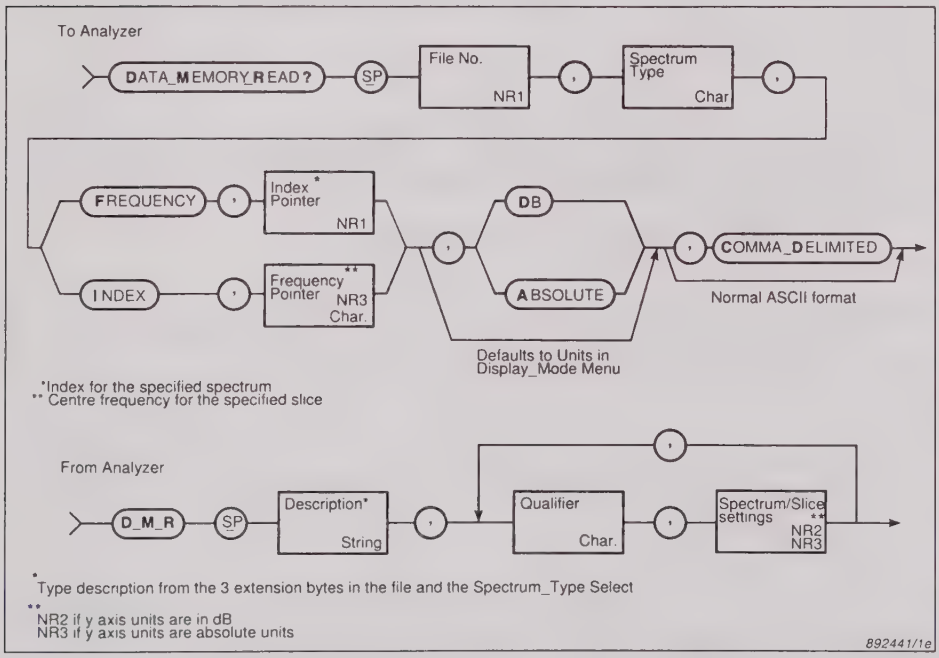

Fig. 8.5 Syntax for the D_M_R? query message and analyzer response

Qualifier can be:

V = Valid
O = Overload
B = Bad
N = Negative
P = Positive

Spectrum_Type can be:

Auto_A
Auto_B
Cross_Re
Cross_Im
Mean_Press
Velocity
Reac_J
Intensity

Examples:

To obtain a readout from spectrum memory in comma delimited format, the controller might send:

```
D-M-R? 1,A-A,F,1,DB,C-D
```

The analyzer responds with (for example):

```
D-M-R "SIMPLE,"1 CH. AUTOSPECTRUM,1/3 OCTAVE,AUTO-A"<CR> <LF>
"V",-385.32 <CR> <LF>
"V",46.54 <CR> <LF>
"V",80.53 <CR> <LF>
.
.
.
.
"V",73.63<SUB>
```

50 Values

To obtain a readout from spectrum memory in Normal ASCII format, the controller might send:

```
D-M-R? 1,A-A,F,1,DB
```

The analyzer responds with (for example):

```
D-M-R "SIMPLE,2 CH. AUTOSPECTRUM,1/3 OCTAVE,AUTO-A",V-256.00,V,-25 etc.
```

8.6 Current_Spectrum_Read?(C_S_R?)

Current_Spectrum_Read? (query only) returns a readout of results from the current displayed spectrum. The start frequency of the readout, which spectrum, and the number of values read out can be specified. The readout may be in dB or absolute units. The data fields and codes are listed in Table 8.2.

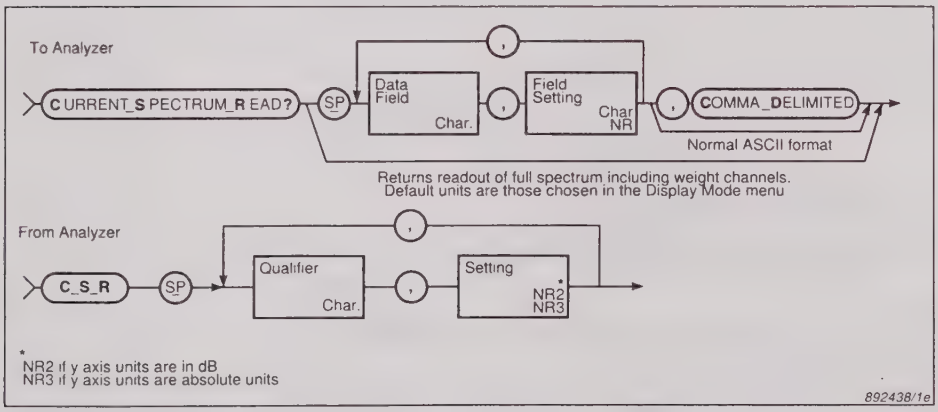

Fig. 8.6 Syntax for the C_S_R? query message and analyzer response

Field Name	Field Setting	Data Type	Comments
STart	<numeric> **A**nalog_**W**eight_**C**hannel **D**igital_**W**eight_**C**hannel	NR3 Char.	Default is the first frequency band
Number	<numeric> **M**ax	NR1 Char.	Default is one band
Y_Axis_**U**nit	**D**b **A**bsolute	Char.	Defaults to units chosen in Display Mode Menu
SPectrum	**U**pper **L**ower	Char.	Defaults chosen in Measurement Mode

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Table 8.2. List of Current_Spectrum_Read? data fields and codes

Qualifier can be:

V = Valid
O = Overload
B = Bad
P = Positive
N = Negative

Examples:

Full Spectrum
To obtain a readout of the current spectrum in full, the controller sends:

```
C_S_R?
```

The analyzer responds with (for example).

```
C_S_R V,79.75,V,81.91,V,86.41,V,68.23,V etc.
```

Partial Readout
To obtain a readout of a defined part of the current spectrum, the controller might send:

```
C_S_R? STA,1K,N,3,Y_A_U,DB
```

The analyzer responds with (for example):

```
C_S_R V,119.94,V,98.00,V,79.28
```

8.7 Print_Screen? (P_SC?)

Print_SCreen? (query) reads out a copy of the current analyzer screen to a hard-copy printer. This message has the same function as manual operation of the **"Hard Copy"** push key on the analyzer front panel (see also section 4.3).

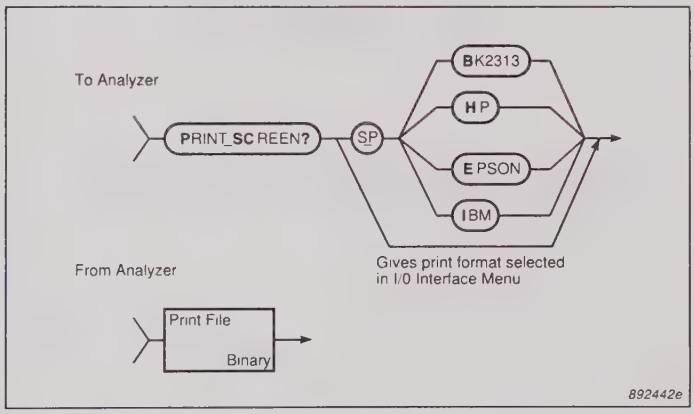

Fig. 8.7 Syntax for the P_SC? query message and analyzer response

Chapter 9

Interface Error Messages

9.1 Introduction 9–2

9.2 How to Cancel an Error 9–2

Manual Cancellation 9–3
Cancellation by a Controller 9–3

9.3 List of Error Messages 9–4

9.1 Introduction

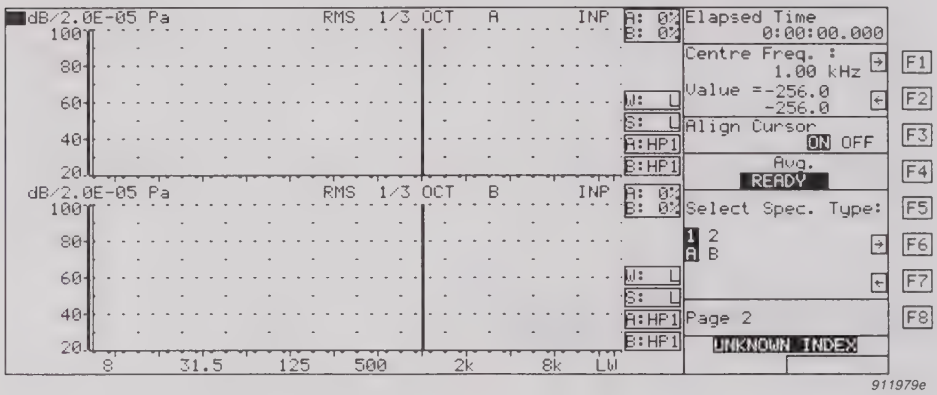

Fig. 9.1 The 2144 displaying an interface error message

Error messages are displayed at the bottom of the right hand side of the analyzer screen, as shown in the example in Fig. 9.1, or read out over the interface using the **ER**ror? query message (see section 8.1). Error cancellation is described in section 9.2, and all the interface error messages are listed in section 9.3, with a brief explanation.

9.2 How to Cancel an Error

9.2.1 Manual Cancellation

You can cancel an interface error manually by:

- Pressing soft key **"F4"** RESET ERROR in page 1 of the I/O Interface menu
- Setting the interface to INACTIVE by pressing soft key **"F2"** in page 1 of the I/O Interface menu
- Pressing the **"Reset"** hard key on the analyzer front panel

9.2.2 Cancellation by a Controller

A controller can cancel an interface error over the interface by:

- Sending a Device Clear (DCL) or Selected Device Clear (SDC), (IEEE–488 only)
- Conducting a serial poll if the SRQ Abnormal mask bit has been set (IEEE–488 only)
- Sending a <Break> (RS–232–C only).

9.3 List of Error Messages

Error no.	Error Message	Description
000	NO INTERFACE ERROR	No interface error detected since last readout of ERror?
001	NO LISTENERS	The IEEE–488 interface is addressed to talk, but no connected device is addressed to listen
002	MESSAGE CANCELLED	The previous interface query message was cancelled because: a) data reception was started, or b) a Device Clear (DCL or SDC) command was received
003	IN REMOTE	Manual addressing/unaddressing[1] was attempted with the 2144 set to Remote by a controller
004	IN ADDR MODE	Manual addressing/unaddressing[1] attempted while the 2144 was addressed by a controller
006	IN TALK MODE	Manual addressing/unaddressing[1] attempted with the 2144 in talk mode
007	IN LISTEN MODE	Manual addressing/unaddressisng[1] was attempted when 2133 is in listen mode
008	USER DATA ONLY	Internal error — please report to B & K
010	NOT IN JDTS	Internal error — please report to B & K
011	NOT IN JNRS	Internal error — please report to B & K
012	NOT IN JRYS	Internal error — please report to B & K
013	NOTHING TO SEND	A query message was sent, but no data was generated
014	HANDSHAKE ERROR	The interface is addressed to talk by a controller, but no listener(s) is active on the bus
022	OVERRANGE	A numeric (NRx) with an absolute value > 32767 has been received
023	NOT A COMMAND	A "query only" was received without a "?"

[1] The 2144 is Manually Addressed to listen, when the Listen Only key in the I/O INTERFACE menu is pressed T03171GB0
Manual Addressing to talk is performed by pressing the Hard Copy key
Manual unaddressing is performed by pressing one of the above mentioned keys a second time

Table 9.1(a) 2144 interface error messages

Error no.	Error Message	Description
024	NOT A QUERY	A "command only" was received with a "?"
026	TOO MUCH DATA	Too many data items were received for this command message
027	MORE DATA EXPECT.	More data items are needed for this command or query message
028	ILLEGAL DATA TYPE	Another data type expected with this message
029	ILLEGAL DATA	Unspecified error in a data field or setting
030	NOT A CONTROLLER	Internal error — please report to B & K
032	AUTOSEQ. ACTIVE	Interface operation is illegal during learning or execution of an autosequence
033	CHAR EXPECTED	Char. Data was expected with current command/query or data field
034	INTEGER EXPECTED	Integer (NR1) was expected with current command/query or data field
035	NUMERIC EXPECTED	Numeric Data (NRx) was expected with current command/query or data field
036	STRING EXPECTED	String Data was expected with current command/query or data field
037	BLOCK EXPECTED	Block was expected with current command-/query or data field
038	ILL. INPUT VALUE	Numeric input value outside allowable range
039	NOT SELECTABLE	Attempted selection is not possible with current instrument setup
040	BAD FILE NAME	File name is incorrect or outside limits (0 to 1000)
041	FILE NOT FOUND	File with the specified file name does not exist

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Table 9.1(b) 2144 interface error messages

List of Error Messages

Error no.	Error Message	Description
042	DIRECTORY FULL	The spectrum memory directory already contains 111 files
043	ALREADY EXISTS	Specified filename has already been allocated to an existing file
044	NO MEMORY SPACE	The spectrum memory is full
045	SPECT. MEMORY ERR	Error occured during a spectrum memory operation
046	IEEE INACTIVE	An attempt was made to execute an "IEEE only" message[2] via the RS-232 interface
052	NOT IMPLEMENTED	Internal error — please report to B&K
053	WRONG TERMINATION	A wrong terminator or separator (or an illegal char. in numeric data) was received
054	ILLEGAL CHAR	A character illegal in current command/query or data type was received
055	MISSING CHARACTER	The END message [3] was received before the message was completed
056	BUFF OVERFLOW	Receive buffer "overflowed" by a numeric input which was too long
057	NOT ALLOWED	Internal error — please report to B&K
060	UNKNOWN INDEX	Character data not legal with the current command/query or parameter was received
061	DUPLICATE INDEX	Internal error — please report to B&K
062	UNKNOWN TABLE	Internal error — please report to B&K
063	ILLEGAL NR1	Numeric data received did not conform to correct NR1 syntax
064	ILLEGAL NR2	Numeric data received did not conform to correct NR2 syntax
065	ILLEGAL NR3	Numeric data received did not conform to correct NR3 syntax

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[2] A few command/querys can only be used via the IEEE488 interface
[3] The End or Identify line — EOI set TRUE

Table 9.1(c) 2144 interface error messages

Error no.	Error Message	Description
066	EXPONENT OVERFLOW	Max. 2 digits are allowed in an exponent
067	ILLEGAL STRING	Incorrect syntax for string data
068	BAD BLOCK SPEC	Message included an block length specification > 32759
069	ILL. BLOCK TYPE	An indefinite block length specification was received via the RS-232 interface
071	BLOCK UNCOMPLETED	An END message [3] was received before the complete block was received
072	BLOCK OVERRUN	Internal error — please report to B&K
073	PREFACE RANGE ERR	A bad block-preface specification was received
074	PREFACE LGT. ERR.	The previously specified block preface does not match the current query message
081	PARITY ERROR	Parity error was detected during RS-232 reception
082	FRAMING ERROR	A framing error was detected during RS-232 reception
083	PAR. & FRAM. ERR	Both parity- and framing errors were detected during RS-232 reception
084	RS-232 OVERRUN	An 1-byte-hardware-buffer overrun error was detected during RS-232 reception
085	PAR.ERR. & OVERRUN	Both parity and overrun errors were detected during RS-232 reception
086	FRAM.ERR. & OVERRUN	Both framing and overrun errors were detected during RS-232 reception
087	PAR.& FRAM.& OVERRUN	Parity, framing and overrun errors detected during RS-232 reception
090	CTS OFF	Internal error — please report to B&K
091	DSR OFF	The DSR line of the RS-232 interface was detected OFF
092	CTS ON	Internal error — please report to B&K
093	RS-232 RX OVERRUN	An overrun of the RS-232 software receive buffer has occurred. Use proper handshaking
094	8 DATABITS NEEDED	7 Data Bits can not be used for block data transfer

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[3] The End or Identify line — EOI set TRUE

Table 9.1(d) 2144 interface error messages

Chapter 10

Data Formats

10.1 Introduction 10–2

10.2 Conventions for Filenames 10–2

10.3 Description of the Parameters 10–4

General Rules 10–4
Setup Information 10–8
Data Information 10–15

10.1 Introduction

This chapter presents information, which, combined with a reasonable knowledge of the PASCAL programming language (eg. TURBO PASCAL), enables you to construct a computer program for accessing data files from the 2144 analyzer. The reader is assumed to be familiar with the way the PASCAL programming language physically handles enumerated TYPES and RECORDS. Therefore PASCAL syntax is used for the description. It is also included on the 2144 program disk supplied with the analyzer in a file named TYPE2144.DEF.

The parameters in a datafile from the 2144 analyzer are described in detail in sections 10.3.1 to 10.3.3. The file TYPE2144.DEF on the program disk contains the TURBO PASCAL type definitions listed in sections 10.3.2 and 10.3.3. "Datafile" in this context means an analyzer file stored on floppy disk, or the block data part of an interface file transfer (IEEE–488 or RS–232–C). Section 10.3 gives a physical description of the location and size of the parameters. All possible values of all parameters in the measurement setup are presented. However, no information on the logical relations between the parameters are included.

Notes:

- The response to a current spectrum command is not a file transfer because no setup is included, only the spectrum part of the "spectrum_record_type" is transferred.
- A datafile larger than 10240 bytes is transferred (using IEEE–488 or RS–232–C) as a number of blocks, in compliance with IEEE standard 488.2. Each of these is preceded by an IEEE block header (see section 4.2.4), which **must** be removed in order to obtain the contents of the datafile.

10.2 Conventions for Filenames

The files stored on floppy disk are given filenames conforming to PC/MS-DOS conventions. The 2144 analyzer has no sub-directories. The filenames are allocated according to the following system:

Filename : klm.xyz , where

k,l,m are INTEGER's (0 .. 9), but k = l = m = 0 is illegal,

x = M for "multi" spectrum file,
S for "single" spectrum file,
B for "multi" spectrum file using Boom/Mux,

y = A for 1/1 octave filter bandwidth,
B for 1/3 octave filter bandwidth,
C for 1/12 octave filter bandwidth,
D for 1/24 octave filter bandwidth,

z = A not used
B not used
C not used
D for measured 1 ch. auto spectrum,
E for measured 2 ch. auto spectrum,
F for measured cross spectrum,
G for measured sound intensity,
H for calculated 1 ch. auto spectrum,
I for calculated 2 ch. auto spectrum,
J not used
K for calculated cross spectrum,
L for calculated sound intensity,
M for measured 1 ch. auto spectrum with HWF,
N for measured 2 ch. auto spectrum with HWF,
O for measured cross spectrum with HWF,
P for measured sound intensity with HWF,
Q not used,
R for corrected sound intensity.

Note:

In the above list, the term HWF is used to indicate a non-fatal hardware failure in the analyzer. If the built-in selftest (executed at "power-on") detects this kind of failure, all files stored subsequently then have a modified last character in the file extension.

10.3 Description of the Parameters

10.3.1 General Rules

Storage of Measurement Data.

The dB-value of a specific filter output (data_value) is stored in a SIGNED INTEGER and the wanted REAL value is found by multiplying by 0.01176 dB (calculated as 10/256log(2) dB). The resolution is twice this value. For intensity measurements the rightmost bit (the least significant bit) is used for indication of intensity in the "negative" direction.

If a user-defined dB-reference is selected, the corresponding dB_offset must be taken into account. The appropriate formula in this case is (data_value+dB_offset*2) * 0.01176 dB. The dB_offset is located in the calibration_setup and possible values are within the range [-512...512] dB.

There are two ways of obtaining the absolute value:

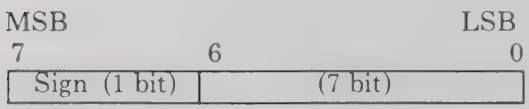
- data_value * 0.01176 dB relative to the standard dB-reference.
- (data_value+dB_offset*2) 0.01176 dB relative to the user-defined dB reference.

ASCII Data

The 2144 uses the ASCII coding as specified in "ANSI X 3.4 - 1986, American National Standard Code for Information Interchange Coded Character Set – 7 - Bit"

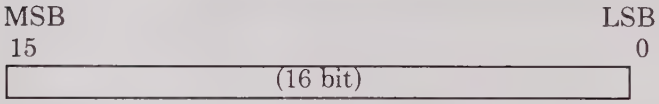
Byte

8 bit, signed binary format.
Range: -128 to 127.



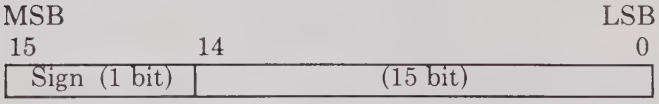
Word

16 bit, unsigned binary format.
Range: 0 to 65535



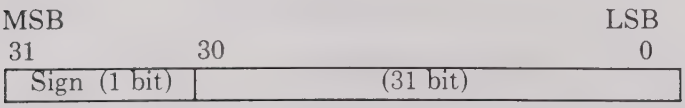
Integer

16 bit, signed binary format – two's complement.
Range: -32768 to 32767



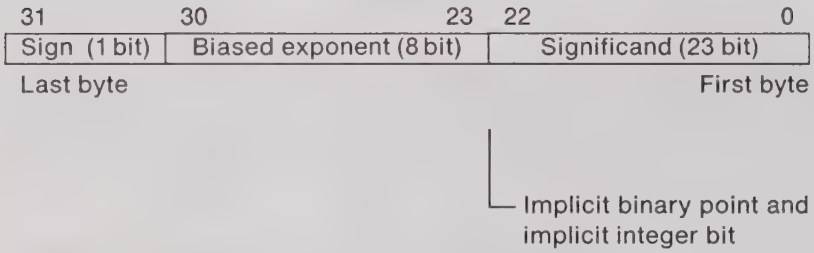
Long Integer

32 bit, signed binary format – two's complement.
Range: -2^{-31} to 2^{31}



Floating Point Number (Real)

32 bit, signed binary format – two's complement.
Range: $8.43 \times 10^{-37} \leqslant$ absolute value $\leqslant 3.37 \times 10^{+38}$
Exponent bias: 127
Significand: fractional part.
The Floating Point Number conforms to the IEEE standard format for a Short Real.



To convert a decimal value to real representation:

Decimal value	= + 178.125
Binary equivalent	= + 10110010.001 (B)
Expressed with decimal exponent	= + 1.0110010001 E7 (B)
With biased decimal exponent	= + 1.0110010001 E134 (127 + 7) (B)
With biased binary exponent	= + 1.0110010001 E 10000110 (B)
With sign	= 0 1.0110010001 E 10000110 (B)

The integer bit and binary point are omitted as they are implicit.

Single real representation = 0 10000110 01100100010000000000000

Hexadecimal representation:

Binary	Hex	
00000000	00	Least significant byte, lowest address in memory.
00100000	20	
00110010	32	
01000011	43	Most significant byte, highest address in memory.

Storage of "enumerated types"

Example:

```
TYPE
     direction_type = (north, east, south, west);
     distance_type  = ARRAY [direction_type] of INTEGER;
```

A variable of an enumerated type is stored in one byte, where north, east, south and west are represented by 0, 1, 2 and 3 respectively. The distance_type shown thus occupies 4 * 2 = 8 bytes of storage.

Calculation of CRC

The CRC (Cyclical Redundancy Check) checksum is calculated by the CRC-16 algorithm with the starting value 5555 (hexadecimal). The CRC value always occurs as the last field in a record and is obtained by using the algorithm on the preceeding fields starting at the first byte of the first field.

BINARY Data Files

A data file from 2144 is BINARY and consists of two parts :

- setup
- data

organized as in the example (the right-hand column is used for calculating of the size in bytes) :

Example:

```
file2144_type = RECORD
  setup                : file_head_type;                                  433
  data                 : ARRAY[1..#s] of SpectrumRecordType; #s*(60+2*#c*#a)
END;                                        total 433+#s*(60+2*#c*#a) bytes
```

#s equals the number_of_spectrum_records. The constants #a, #c depend on the filter bandwidth, the upper frequency and the type of measurement and are described in section 10.3.3..

10.3.2 Setup Information

The setup information consists of a number of nested RECORD-types utilizing enumerated types. Each of the RECORDs at second level consists of related parameters corresponding to an analyzer menu.

The units are as follows:

- Frequencies are in Hz
- Distances in mm
- Temperatures in °C
- Air Densities in kg/m^3
- Air Pressures in hPa

```
file_head_type  = RECORD
    source_id                   : file_name_t;              8
    total_file_size             : longint;                  4
    number_of_spect_records     : INTEGER;                  2
    spect_record_byte_size      : INTEGER;                  2
    clock                       : time_descr_t;             4
    file_comment                : file_text_t;             40
    measurement_setup           : meas_setup_data_type; 371
    crc                         : INTEGER;                  2
END;                                          total 433 bytes

file_name_t     = ARRAY [1..8] OF CHAR;                   8 byte

file_text_t     = ARRAY [1..40] OF CHAR;                 40 byte

longint         = ARRAY [significance] OF INTEGER;        4 byte

significance    = (lsword,msword);                        1 byte

time_descr_t    = RECORD
    hour_min_sec: INTEGER;                                  2
    year_mon_day: INTEGER;                                  2
END;                                          total     4 bytes
```

Note:

The MS-DOS Time/Date Format is used. The time and date are contained in four bytes, and can be considered as two words; the first representing hours/minutes/seconds, the second year/month/day.

Thus, Word 1 is subdivided as follows:

Bit 0..4 : number of two-second increments
Bit 5..10 : minutes
Bit 11..15 : hours

Word 2 is subdivided as follows:

Bit 0..4 : day
Bit 5..8 : month
Bit 9..15 : year

```
meas_setup_data_type     = RECORD
    spectrum_id          : spect_id_type;                1
    meas_type            : meas_type_t;                  1
    meas_mode            : meas_mode_status;             3
    calib                : calibration_setup;           74
    input                : input_setup;                 39
    filter_bw            : filter_bw_setup;              7
    averaging            : averaging_setup;              8
    hold                 : hold_setup;                  14
    trigger              : trigger_setup;               57
    weight               : spectrum_weight_setup;       12
    display              : display_setup;               42
    bm_param             : bm_param_setup;              11
    unused_bytes         : ARRAY [1..100] OF byte;     100
    crc                  : INTEGER;                      2
END;                                    total 371 bytes
```

Note:

"unused_bytes" is reserved for future use. Until then these bytes will contain the value zero.

```
spect_id_type    = (autospectrum_1ch,autospectrum_2ch,
                    crossspectrum,intensitymode,
                    calculated_1ch,calculated_2ch,
                    calculated_cross,calculated_intensity,
                    hwf_1ch,hwf_2ch,hwf_cross,
                    hwf_intensity,
                    correction_intensity);              1 byte

meas_type_t      = (one_ch,two_ch,intensity_pp,
                    cross_spec);                        1 byte

meas_mode_status          = RECORD
    hold_condition        : condition_type;                 1
    display_hold          : condition_type;                 1
    external_sampling     : BOOLEAN;                        1
 END;                                          total    3 bytes


condition_type   = (active,inactive);                     1 byte

byte     = -128..127;                                     1 byte



calibration_setup         = RECORD
    calib                 : ARRAY [input_ch_type] OF
                            calib_setup_ch;              32
    dens_param            : dens_param_t;                   1
    nominal_spacing       : INTEGER;    (in mm)             2
    temperature           : REAL;       (in °C)             4
    air_pressure          : REAL;       (in hPa)            4
    nominal_density       : REAL;       (in kg/m3)          4
    user_density          : REAL;       (in kg/m3)          4
    dB_offset             : dB_offset_type;                 6
    calib_level_ab        : REAL;                           4
    corr_high_range       : REAL;                           4
    corr_low_range        : REAL;                           4
    corr_time             : time_descr_t;                   4
    corr_spect_on         : BOOLEAN;                        1
END;                                           total   74 bytes


input_ch_type    = (ch_a,ch_b);                           1 byte

calib_setup_ch            = RECORD
    ref_level             : REAL;                           4
    ref_ch_freq           : REAL;                           4
    trans_sens            : REAL;                           4
    gain_adj              : REAL;                           4
END;                                           total   16 bytes
```

```
dens_param_t            = (air_dens,user_dens);          1 byte

dB_offset_type          = ARRAY [dB_offset_spec_type_t]
                          OF INTEGER;                    6 byte

dB_offset_spec_type_t   = (offset_AA, offset_BB,
                           offset_AxB);                  1 byte


input_setup             = RECORD
    input               : ARRAY [input_ch_type] OF
                          input_sel_type;                 2
    input_set           : ARRAY [input_sel_type,
                                 input_ch_type] OF
                                input_setup_ch;          36
    analogue_ground     : BOOLEAN;                        1
END;                                          total  39 bytes


input_setup_ch          = RECORD
    input_filter        : input_filter_type;              1
    low_pass_filter_on  : BOOLEAN;                        1
    attenuator_level    : INTEGER;                        2
    max_level           : INTEGER;                        2
END;                                          total   6 bytes

input_sel_type  = (preamp,direct,charge);                 1 byte

input_filter_type       = (hp03,hp20,hp100,A);            1 byte


filter_bw_setup         = RECORD
    filter_bw           : filter_bw_type;                 1
    pass_no             : pass_no_type;                   1
    multi_pass_mode     : pass_mode_type;                 1
    lowest_reliable_freq: REAL;                           4
END;                                          total   7 bytes
```

```
filter_bw_type   = (oct1,oct3,oct12,oct24);                    1 byte

pass_no_type     = (pass0,pass1,pass2,pass4,pass8);            1 byte

pass_mode_type   = (automatic,manual);                         1 byte


averaging_setup           = RECORD
    averaging_mode        : averaging_mode_type;                    1
    lin_avg_hours,                                                  1
    lin_avg_min,                                                    1
    lin_avg_sec           : byte;                                   1
    lin_avg_ms            : INTEGER;                                2
    exp_avg_time_index    : INTEGER; (512s:9;1/512s:-9)             2
END;                                              total    8 bytes


averaging_mode_type       = (lin,exp);                         1 byte


hold_setup                = RECORD
    setup                 : ARRAY [1..2] OF
                            hold_setup_set;                        14
END;                                              total   14 bytes


hold_setup_set            = RECORD                                  1
    maximum               : BOOLEAN;                                1
    hold                  : hold_type;                              1
    hold_ch_freq          : REAL;                                   4
    hold_spec             : spectrum_select_type;                   1
END;                                              total    7 bytes
```

```
hold_type        = (inactive_hold,all_hold,
                    a_l_hold,w_hold,b_p_hold);          1 byte

spectrum_select_type     = (autoA,autoB,crossR,crossI,
                            meanpress,velocity,intensityR
                            intensityA,phase,amplitude,
                            coherence,H1,H2,H3);        1 byte


trigger_setup    = RECORD
    trig_active          : condition_type;                  1
    trig_select          : trigger_select_type;             1
    trig_avg             : trigger_avg_type;                1
    trig_spec            : spectrum_select_type;            1
    trig_slope           : trigger_slope_type;              1
    trig_level           : REAL;                            4
    trig_ch_sel          : ch_sel_type;                     1
    trig_ch_freq         : REAL;                            4
    trig_time_delay      : ARRAY [normal..gated] OF REAL;   8
    trig_no_of_spec      : ARRAY [normal..gated]
                           OF INTEGER;                      4
    trig_no_of_pre_spec  : INTEGER;                         2
    trig_no_of_trig      : INTEGER;                         2
    trig_time_interval   : ARRAY [normal..gated] OF REAL;   8
    trig_hours,                                             1
    trig_min,                                               1
    trig_sec             : byte;                            1
    trig_rep_sec         : INTEGER;                         2
    trig_rows            : INTEGER;                         2
    trig_columns         : INTEGER;                         2
    trig_directions      : byte;                            1
    trig_sequence        : trig_sequence_t;                 1
    trig_row_space       : REAL;     (in mm)                4
    trig_column_space    : REAL;     (in mm)                4
END;                                          total  57 bytes


trigger_select_type      = (int_trig,ext_trig,clock_trig,
                            manual_trig,free_run);      1 byte

trigger_avg_type         = (normal,gated,matrix);       1 byte

trigger_slope_type       = (negative,positive);         1 byte

rig_sequence_t = (dcr,drc,cdr,crd,rdc,rcd);             1 byte

ch_sel_type      = (AL_ch,W_ch,Sel_ch);                 1 byte
```

Note:

The order of measurement (and storage) for [trig_sequence = cdr] of a matrix multispectrum with 2 rows, 2 columns and 2 directions is:

(column, direction, row) = (1,X,1), (2,X,1), (1,Y,1), (2,Y,1), (1,X,2), (2,X,2), (1,Y,2), (2,Y,2)

The last "index" in the trig_sequence is thus changing slowest, the first "index" fastest.

```
spectrum_weight_setup   = RECORD
    weight_select       : ARRAY [weight_on_t] OF
                          weight_selection;              12
END;                                          total  12 bytes

weight_selection        = RECORD
    weight              : weight_type;                    1
    invers              : BOOLEAN;                        1
    user_weight_date    : time_descr_t;                   4
END;                                          total    6 bytes

weight_on_t     = (spectrum,w2);                        1 byte

weight_type     = (w_L,w_U1,w_U2,w_U3,w_U4,w_A,
                   w_B,w_C,w_D);                        1 byte

display_setup   = RECORD
    select_spec         : ARRAY [display_sel_t] OF
                          spectrum_select_type;         2
    full_scale          : ARRAY [display_sel_t]
                          OF INTEGER;                   4
    dB_range            : ARRAY [display_sel_t]
                          OF dB_range_type;             2
    spectrum_unit       : ARRAY [display_sel_t]
                          OF spectrum_unit_type;        2
    spectrum_mode       : ARRAY [display_sel_t]
                          OF byte;                      2
    phase_range         : ARRAY [display_sel_t]
                          OF phase_range_type;          2
    cursor_ch_type      : ARRAY [display_sel_t]
                          OF ch_sel_type;               2
    cursor_ch_freq      : ARRAY [display_sel_t] OF REAL;  8
    dB_diff_range       : dB_range_type;                  1
    display_mode        : display_mode_type;              1
    y_axis_unit         : y_axis_unit_type;               1
    polar               : polar_type;                     1
    display_freq_low    : REAL;                           4
    first_ch_freq,                                        4
    last_ch_freq        : REAL;                           4
    align_cursor        : condition_type;                 1
    disp_selector       : display_sel_t;                  1
END;                                          total  42 bytes
```

```
display_sel_t    = (upper,lower);                          1 byte

dB_range_type    = (db1,db5,db10,db20,db40,db80);          1 byte

spectrum_unit_type       = (PWR,RMS,ENERGY,PSD,ESD);       1 byte

phase_range_type         = (dg02,dg1,dg5,dg45,
                            dg90,dg180);                   1 byte

display_mode_type        = (single_display,
                            dual_display,
                            difference_display);           1 byte

y_axis_unit_type         = (decibel,e_unit);               1 byte

polar_type       = (unipolar,bipolar);                     1 byte


bm_param_setup   = RECORD
    appl_boom_mux_mode                 : condition_type;   1
    autorange                          : condition_type;   1
    sound_source_on_time               : INTEGER;          2
    number_of_pos                      : byte;             1
    position_number                    : byte;             1
    evaluation_range_for_estimated_rt  : byte;             1
    select                             : bm_select_t;      1
    sound_source                       : bm_snd_source_t;  1
    equipment_type                     : bm_equipment_t;   1
    measurement_position               : bm_meas_pos_t;    1
END;                                        total  11 bytes


bm_select_t      = (bm_decay,bm_spl);                      1 byte

bm_sound_source_t        = (bm_off,bm_1on,bm_2on,
                            bm_1_2on);                     1 byte

bm_equipment_t   = (bm_boom,bm_mux,bm_none);               1 byte

bm_meas_pos_t    = (bm_single,bm_step,bm_rotating);        1 byte
```

10.3.3 Data Information

The data information consists of these RECORD-types :

```
SpectrumRecordType       = RECORD
    srh          : SpectrumRecordHead;                      58
    spectrum     : ARRAY [1..#a] OF Spectrum_t;      2*#c*#a
    crc          : INTEGER;                                  2
END;                                    total 2*#c*#a+60 bytes
```

```
SpectrumRecordHead      = RECORD
    word_size                              : INTEGER;        2
    head_word_size                         : INTEGER;        2
    spectrum_word_size                     : INTEGER;        2
    internal_use_1                         : ARRAY [1..9]
                                             OF INTEGER;    18
    overload_level_A                       : INTEGER;        2
    internal_use_2                         : ARRAY [1..4]
                                             OF INTEGER;     8
    overload_level_B                       : INTEGER;        2
    internal_use_3                         : ARRAY [1..11]
                                             OF INTEGER;    22
END;                                           total 58 bytes

Spectrum_t      = ARRAY [1..#c] OF INTEGER;      2*#c bytes
```

Parameters in Spectrum Record Size

word_size: Spectrum Record Type size is twice this value
head_word_size: Spectrum Record Head size is twice this value
spectrum_word_size: constant #c in Table 10.2 equals this value
overload_level_A(B): the overload %s are these values /100

#s equals the number_of_spectrum_records. The constants #a and #c depend on the filter bandwidth, the upper frequency of analysis and the type of measurement as shown in Tables 10.1 and 10.2.

#a	value	order of storage of spectrum types
1 ch. auto spectrum	1	A
2 ch. auto spectrum	2	A B
sound intensity	4	P V J I
cross spectrum	4	A B Re Im

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Table 10.1 Values of #a

#c	1/1 octave	1/3 octave	1/12 octave	1/24 octave
22.4 kHz (1 ch. auto spectrum)	16 + 2	48 + 2	192 + 2	384 + 2
11.2 kHz (2 ch. auto spectrum)	15 + 2	45 + 2	180 + 2	360 + 2
11.2 kHz (sound intensity)	15 + 2	45 + 2	180 + 2	360 + 2
11.2 kHz (cross spectrum)	15 + 2	45 + 2	180 + 2	360 + 2
11.2 kHz (1 ch. auto spectrum)	N/A	N/A	180 + 2	360 + 2
5.6 kHz (2 ch. auto spectrum)	N/A	N/A	168 + 2	336 + 2
5.6 kHz (sound intensity)	N/A	N/A	168 + 2	336 + 2
5.6 kHz (cross spectrum)	N/A	N/A	168 + 2	336 + 2
5.6 kHz (1 ch. auto spectrum)	N/A	N/A	168 + 2	336 + 2
2.8 kHz (2 ch. auto spectrum)	N/A	N/A	156 + 2	312 + 2
2.8 kHz (sound intensity)	N/A	N/A	156 + 2	312 + 2
2.8 kHz (cross spectrum)	N/A	N/A	156 + 2	312 + 2
2.8 kHz (1 ch. auto spectrum)	N/A	N/A	N/A	312 + 2
1.4 kHz (2 ch. auto spectrum)	N/A	N/A	N/A	288 + 2
1.4 kHz (sound intensity)	N/A	N/A	N/A	288 + 2
1.4 kHz (cross spectrum)	N/A	N/A	N/A	288 + 2

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Table 10.2 Values of #c

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